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ABSTRACT

Listed in this science syllabus are concepts and understandings in five areas of astronomy (earth, studying the heavens, earth's moon, the sun and other stars, and the solar system) and two areas of aerospace science (flight in air and flight in space). Included with these The booklet also includes questions for students to answer and, when applicable, a code to an activity presented in the appendix. Program objectives and performance criteria are provided for the five astronomy and two aerospace science areas, as is a list of 23 science processes keyed to the activities. All of the 63 activities (designed to assist students in attaining the program objectives) include a list of materials needed, procedures, and discussion of results. (JN)

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ASTRONOMY & AEROSPACE SCIENCE

Science Syllabus for Middle and Junior High Schools

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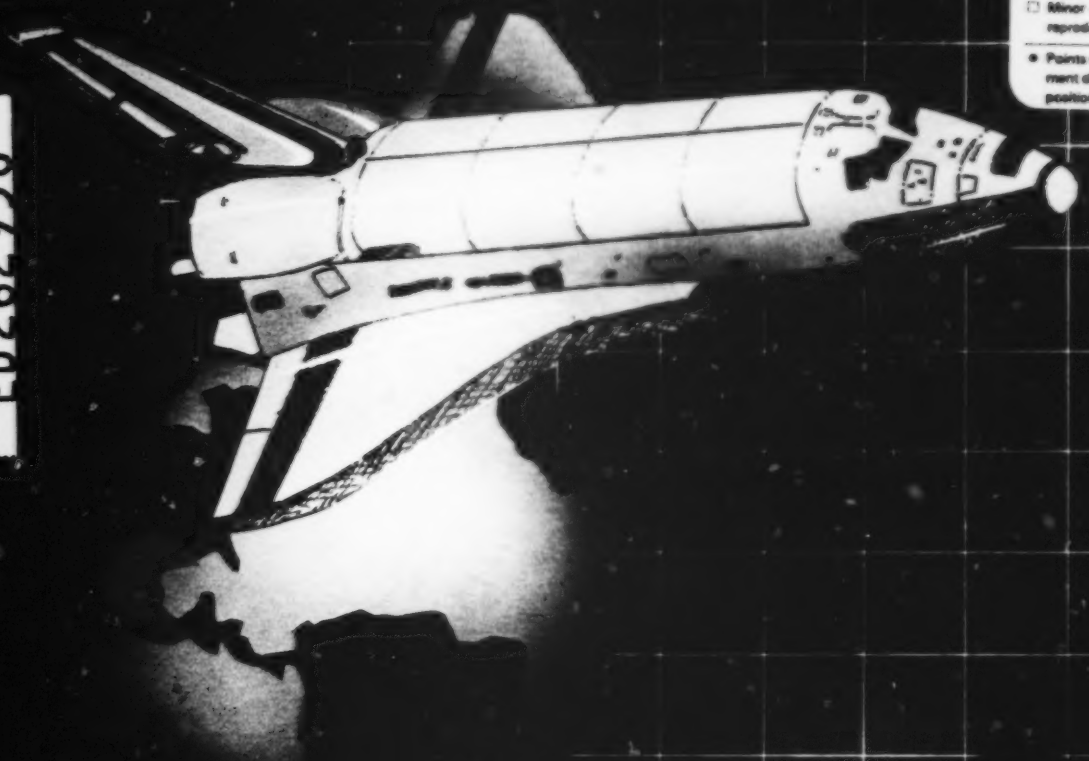

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BLOCK F

SCIENCE SYLLABUS FOR MIDDLE AND JUNIOR HIGH SCHOOLS

BLOCK F: ASTRONOMY AND AEROSPACE SCIENCE

The University of the State of New York
The State Education Department
Albany, New York 12234
(1985)

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FOREWORD

This publication is the ninth product of the project to significantly update and reorder the Science Syllabus for Middle and Junior High Schools. The project will result in a group of instructional blocks encompassing the content and skills in the biological, physical, and earth sciences appropriate for those grade levels.

The understandings, questions, and learning activities in the publication have been enhanced by the inclusion and referencing of program objectives, performance criteria, and process skills which serve to focus student achievement.

Objectives and performance criteria are provided in a general outline which conforms to the content subdivisions in the publication. Process skills are keyed to the learning activities (**Appendix A**), and the learning activities are keyed to the understandings and the questions. Resources related to these activities are found in **Appendix B**.

The first draft of this publication was prepared by **Donna E. DeSeyn**, Fairport Central School. Subsequent revisions were made by **Nancy Spaulding**, Elmira City Schools and **Frances Hess**, Cooperstown Central School.

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Douglas S. Reynolds, Chief, and **Thomas Boehm**, Associate, Bureau of Science Education made important contributions to the project's development. Graphics were provided by the **Center for Art and Design**

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PROGRAM OBJECTIVES AND PERFORMANCE CRITERIA

I. ASTRONOMY

Program Objectives	Performance Criteria
The student will be able to identify some effects of Earth's rotation.	Given a list of events which occur on Earth, the student will identify those events which result from Earth's rotation.
The student will be able to identify some events which are the result of Earth's revolution.	Given a list of events which occur on Earth, the student will select those which are the result of Earth's revolution and explain how each results from that revolution.
The student will be able to describe the seasonal changes which occur on Earth and explain why they occur.	Given a season, the student will describe the daylight conditions in New York State during that season and identify the tilt of Earth's axis relative to the Sun. Given a model of Earth, the student will orient the model to demonstrate the causes of seasons.
The student will be able to use two methods to determine the direction of north.	Given a set of circumstances and/or an appropriate piece of equipment, the student will determine the direction of north.
The student will be able to use Earth's latitude-longitude system.	Given a globe or world map, the student will determine the latitude and longitude of any point on that globe or map. Given the latitude and longitude of any location on a globe or map, the student will identify that location.
The student will be able to explain the need for standard time zones, daylight saving time, and the International Date Line.	Given a globe, the student will explain the need for time zones, the International Date Line, and daylight saving time.
The student will be able to describe the instruments used by astronomers to study the heavens.	Given an example of an astronomical instrument, the student will describe its use.
The student will be able to compare conditions on the Moon with those on Earth.	Given a set of statements, the student will identify those which are true on the Moon and those which are true on Earth.
The student will be able to describe and identify the phases of the Moon.	Given a model of the Earth-Moon-Sun system, the student will demonstrate and explain each phase of the Moon.

The student will be able to explain the causes of eclipses of the Sun and Moon.	Given an appropriate model, the student will demonstrate a lunar and a solar eclipse.
The student will be able to explain the occurrence of tides.	Given an appropriate model, the student will explain how the tides occur.
The student will be able to describe several kinds of stars, including our Sun, found in the universe.	Given a list or diagram of kinds of stars, the student will describe the kinds of stars on the list or diagram.
The student will be able to compare and contrast the different kinds of bodies that occur in our solar system.	Given a description of a body in the solar system, the student will identify the body described and compare it to other bodies in the solar system.

II. AEROSPACE SCIENCE

The student will be able to compare and contrast characteristics of lighter-than-air and heavier-than-air flight.	Given examples of lighter- and heavier-than-air flight, the student will describe how they are similar and how they are different.
The student will be able to describe the forces that affect an aircraft's flight and describe how those forces are controlled.	Given a model aircraft, the student will describe the forces that affect the aircraft's flight and identify the location and use of the flight controls.
The student will be able to identify and describe two methods of flight navigation.	Given a location to fly to, the student will describe two methods of navigation that can be used to arrive at that location.
The student will be able to identify several flight instruments and describe the use of each.	Given an example of a flight instrument, the student will describe its use.
The student will be able to compare and contrast several kinds of aircraft.	Given models of aircraft, the student will describe the important characteristics of each model and explain how each differs from other kinds of aircraft in its flight.
The student will be able to describe the forces that affect space flight.	Given an example of a spacecraft being launched from or returned to Earth, the student will identify and describe the forces affecting the spacecraft.
	Given an example of a spacecraft in closed or open orbit, the student will identify and describe the forces affecting the spacecraft.
The student will be able to describe how the safety and comfort of the astronauts are considered when they travel into space.	The student will identify the human needs of an astronaut and describe how those needs are provided for during space flight.
The student will be able to list and describe some benefits and some burdens of the space program.	Given an example of a benefit or burden of the space program, the student will explain how it is a benefit or a burden.
The student will be able to describe some space programs that have been proposed for the future.	Given an example of a proposed space program, the student will identify the purpose of the program, the benefits likely to result from the program, and the problems likely to be encountered in implementing the program.

PROCESSES

One of the major objectives in all science courses is the development of competence in processes used in science. The learning activities beginning on p. 25 in this publication will assist students in attaining this objective. Each activity is keyed to one or more of the processes listed below. For example, activity **(F-1)** involves processes **(1), (2),** and **(29)**.

(1) Observing objects and phenomena
(2) Describing observations
(3) Selecting suitable measuring instruments
(4) Developing skills in using laboratory equipment
(5) Measuring objects and phenomena
(6) Performing laboratory techniques
(7) Estimating measurements within limits of accuracy
(8) Recognizing a problem
(9) Formulating a working hypothesis
(10) Designing appropriate tests of a hypothesis
(11) Designing suitable procedures for experimental tests
(12) Processing experimental data
(13) Organizing data to show a functional relationship
(14) Interpreting observations and data
(15) Interpolating and extrapolating
(16) Evaluating a hypothesis in the light of data obtained
(17) Formulating generalizations based on relationships
(18) Recognizing the need for a theoretical model
(19) Formulating a theoretical model to accommodate knowledge
(20) Designing relationships satisfied by a model
(21) Deducing a hypothesis from a theoretical model
(22) Interpreting and evaluating tests of a model
(23) Producing a revised, refined, or extended model

CONCEPTS AND UNDERSTANDINGS — QUESTIONS AND ACTIVITIES

I. ASTRONOMY

Concepts and Understandings	Questions and Activities

A. EARTH IN SPACE

1. Earth's rotation on its axis

Rotation is one of Earth's two basic motions relative to the Sun.

Where is Earth's axis of rotation? **(T-1)**

a. Evidences of rotation

1) The apparent daily motion of the Sun across the sky suggests that Earth rotates.

What evidences indicate that Earth rotates?

What is meant by "apparent" motion? **(T-2)**

Does the apparent daily motion of the Sun show that Earth rotates?

How would the apparent motion of the Sun differ if Earth did not rotate?

2) The apparent daily motions of the Moon, the planets, and the stars can all be explained by a rotating Earth.

How do the stars appear to move across the nighttime sky? **(T-3)**

How would the apparent daily motions of the Moon, the planets, and the stars differ if Earth did not rotate?

Do the apparent daily motions of the Moon, the planets, and the stars prove that Earth rotates?

3) A freely swinging pendulum appears to change its direction of swing with time. This is an apparent motion caused by the rotation of Earth beneath the pendulum.

How does a Foucault pendulum show that Earth rotates? **(T-4)**

4) Substances, such as air and water, that move freely over Earth's surface are turned to their right in the Northern Hemisphere and to their left in the Southern Hemisphere as a result of Earth's rotation.

How do objects moving over the surface of Earth appear to be deflected? **(T-5)**

How would objects such as rockets be affected by Earth's rotation?

b. Effects of rotation

1) The direction of rotation causes the Sun to rise apparently in or near the east and set in or near the west.

What effect does Earth's rotation have on our daily lives?

What does the direction of sunrise and sunset tell us about the direction of Earth's rotation?

2) Earth's rotation in relation to the Sun causes the daily change from daylight to darkness.

What part of Earth is in darkness at any given time? What causes the change from daylight to darkness? **(T-6)**

3) Earth's rotation causes the length of one day to be about 24 hours.

How do we know when one rotation has been completed?

2. Earth's revolution around the Sun

Revolution is the other of Earth's two basic motions relative to the Sun.

How do we know that Earth is moving around the Sun?

a. Evidences of revolution

1) The stars nearest to us show a definite change in position when compared to the positions of more distant stars.

Why do nearby stars appear to shift positions relative to distant stars? What is parallax displacement? **(T-7)**

How would photographs of the nighttime sky taken six months apart look if Earth did not move around the Sun?

2) From Earth, many stars (constellations) can be seen only during certain months of the year.

What are some constellations that can be seen in the summer? What are some constellations that can be seen in the winter? **(T-8)**

How would the nighttime sky appear over a year if Earth did not revolve around the Sun?

b. Effects of revolution

1) Earth makes one revolution around the Sun in about 365 days. This defines the length of one year.

What effect does Earth's revolution have on our lives?

How do we know when one revolution has been completed?

Why do we have "leap year"?

2) Earth's revolution around the Sun is one of the causes of seasons on Earth.

Would Earth have seasonal change if it did not revolve around the Sun?

c. Cause of Earth's revolution

The interaction of gravity and Earth's inertia cause Earth to revolve around the Sun.

3. Seasons on Earth

a. Causes of seasons

Seasons on Earth are caused by the tilt of Earth's axis of rotation and the revolution of Earth around the Sun.

What effect does the tilt of Earth's axis have on Earth? **(T-9, 10)**

1) Earth's axis is tilted 23.5° to the plane of Earth's

How would summer temperatures be different if

orbit and always points to nearly the same point in space.

Earth's axis is tilted toward the Sun during the Northern Hemisphere summer and away from the Sun during the Northern Hemisphere winter.

2) The changing positions of Earth relative to the Sun as Earth travels around the Sun are necessary for the changing seasons. The changing distance of Earth from the Sun also affects the seasons, but to a much lesser extent.

3) The interaction of Earth's rotation and revolution causes the amount of daylight received by a given location to change daily.

b. Characteristics of Earth's seasons

Earth's seasons, which mark the major time divisions of a year, consist of summer, fall, winter, and spring.

1) Summer

Because the Northern Hemisphere is tilted toward the Sun in summer and the Sun shines more directly on it, the Northern Hemisphere warms.

The longest daylight period of the year occurs on the first day of summer.

Locations above the Arctic Circle experience continuous periods of light for weeks at a time.

2) Winter

Because the Northern Hemisphere is tilted away from the Sun in winter and the Sun shines more directly on the Southern Hemisphere than on the Northern Hemisphere, the Northern Hemisphere cools.

The shortest daylight period of the year occurs on the first day of winter.

Locations above the Arctic Circle experience continuous periods of darkness for weeks at a time.

Earth's axis were tilted more steeply? Less steeply? How would winter temperatures differ if the tilt changed? What general conclusion can be drawn about seasonal temperatures and axial tilt? **(T-8)**

What effect does the unchanging direction in which the axis points have on the position of Earth during the four seasons?

What causes Earth to change distance from the Sun? **(T-11)** What effect would be noticed if we were closer to the Sun in summer than in winter?

How do changing daylight conditions affect the seasons?

What changes occur with each season? **(T-9)**

How many seasons occur in New York State each year? How long is each season?

How does the position and tilt of Earth affect the seasons and length of daylight during the course of a year? **(T-10)**

Why does the Northern Hemisphere warm during summer?

When is the first day of summer in New York State?

Is this day likely to be the hottest day of the year? Why?

What is a solstice?

What is the difference between the length of a day and the daylight period?

How does the daylight period change with the season?

Where is the Arctic Circle? What is the daylight period for every location north of the Arctic Circle on the first day of summer?

What are the daylight conditions in the Southern Hemisphere during the Northern Hemisphere season of summer? What happens within the Antarctic Circle?

Why does the Northern Hemisphere cool during winter?

When is the first day of winter in New York State?

Is this likely to be the coldest day of the year? Why?

What are the daylight conditions for every location north of the Arctic Circle on the first day of winter?

What are the daylight conditions in the Southern

Hemisphere during the Northern Hemisphere season of winter? What happens south of the Antarctic Circle?

3) Spring and Fall

On the first day of spring and on the first day of fall, neither hemisphere is tilted toward the Sun and the Sun is shining directly on the equator. Every location on Earth's surface is experiencing equal periods of daylight and darkness and the Sun appears to rise due east and to set due west on these days.

What is an equinox? Why are daylight and darkness equal everywhere on these days?

What happens to the daylight period in both hemispheres during spring and fall?

What happens within the Arctic and Antarctic Circles during spring and fall?

4. Earth's shape and size

Earth is a sphere about 13,000 km in diameter.

a. Evidences for a spherical shape

What evidence indicates that Earth's shape is spherical?

1) The tops of objects such as ships at sea are the first to appear and the last to disappear over the horizon.

How do we know that Earth is not flat?

How would vessels appear and disappear if Earth were flat?

2) Earth's shadow on the Moon as viewed from Earth during lunar eclipses is always round.

How would a shadow of Earth appear if Earth were disk-shaped? **(F-12)**

3) Photographs of Earth from space show it to be spherical, and other solar system objects such as the Moon and nearby planets are apparently spherical.

What do photos from space show about the shape of Earth? **(F-13)**

4) The apparent position of the North Star and neighboring stars in the sky changes in a regular way with movement north and south over Earth's surface.

Where is the North Star?

What would happen to the position of the North Star if Earth were flat?

5) The weight of a given object is almost the same everywhere on Earth's surface.

What determines the weight of an object? What would happen to the weight of objects if Earth were flat?

b. Finding Earth's size

1) Earth's circumference can be found by measuring the vertical angle of the Sun (or any stars) at the same time at two locations a known distance apart.

When and how was the first fairly accurate determination of Earth's circumference made?

2) Earth's diameter can be found by dividing its circumference by *pi*.

What is Earth's diameter?

5. Determining locations on Earth

Places on Earth are located by using the compass directions, latitude, and longitude.

How do we orient ourselves on Earth?

a. Finding north

1) In the nighttime, north is the direction of a point on Earth directly below the North Star.

Where is the North Star and why is its location in the sky unique?

2) In daytime, the shadow cast by a vertical pole will point north at local (not clock) noon.

In what direction is a shadow cast by a vertical pole at solar noon? **(F-14)**

3) A magnetic compass points to magnetic (not true) north. Magnetic variation is the angle by which the compass needle varies from true north.

b. Latitude

1) The basis of Earth's latitude system is Earth's axis of rotation. The north and south geographic poles mark the ends of the axis on Earth's surface.

What is latitude? **(F-15)**

2) The equator is halfway between the North and South Poles, dividing Earth into northern and southern hemispheres.

What is the latitude of the equator? What is the latitude of the North Pole? The South Pole?

3) Parallels of latitude are lines parallel to the equator. They measure distances in degrees north and south of the equator.

What is an astrolabe and how is it used to find the latitude of a location? **(F-16, 17)**

c. Longitude

1) The basis of Earth's longitude system is the Prime Meridian. The Prime Meridian and the 180th meridian opposite it divide Earth into eastern and western hemispheres. The half of the world that is west of the Prime Meridian has west longitude. The half of the world that is east of the Prime Meridian has east longitude.

What is longitude? **(F-18)**

Where is the Prime Meridian?

Where is New York State relative to the Prime Meridian? What hemisphere is it in?

2) Meridians are lines used to measure the distance, in degrees, east and west of the Prime Meridian. All meridians intersect at the poles.

How can we find the longitude of our school? **(F-19)**

6. Determining time of day

The measurement of hourly time is based on the length of Earth's day.

a. Sun time

1) For many years, the position of the Sun in the sky was the standard for determining time of day. The position of the Sun determines the length of an object's shadow. Noon by Sun time occurs when the shadow cast by a vertical pole is shortest.

How does Earth's rotation relate to the position of the Sun in the sky?

What will the length of a shadow be when the Sun's position is high in the sky? When it is low in the sky?

How is Sun time determined? **(F-20, 21)**

2) The time from one noon Sun to the next noon Sun (one rotation of Earth) is one solar day.

3) For centuries, the shadow cast on a sundial was the most accurate method of measuring time.

What are the parts of a sundial?

How is a sundial made? **(F-22)**

b. Clock time

1) Clock time is based on the average length of a solar

How does clock time compare with Sun time? **(F-23)**

day. Noon by clock time is seldom the same time as noon by Sun time.

2) A pendulum can be used as a clock because the time of its swing is very regular. More recently developed clocks include the quartz-crystal and the atomic clock.

What kinds of clocks are most accurate?

c. Standard time

1) Standard time is based on the time in Greenwich, England. There are 24 time zones which correspond to the Sun's apparent motion of 15° per hour across the sky. Each time zone is a longitude belt 15° wide. All areas in a time zone have the same local time. Local time is one hour earlier as a traveler moves westward from one zone to the next.

Why is standard time important to us?

How many time zones are there? How are the time zones arranged?

Why was Greenwich used as the starting point for standard time?

2) Excluding Alaska and Hawaii, there are four standard time zones in the United States.

What are the names of the four time zones located in the United States?

What is the time difference between New York and California?

What do you see regularly on television that emphasizes the time differences across the United States?

d. Daylight saving time

Daylight saving time extends daylight one hour later in the evening, starting in late April and ending in late October.

Are clocks set ahead or back in April? In October?

How do the time zones shift when we move to daylight saving time?

Why do we move to daylight saving time?

e. International Date Line

1) The International Date Line roughly follows the 180th meridian and keeps calendar dates adjusted around the world.

Why is the International Date Line necessary? **(F-24)**

How does the day vary around Earth in the course of a 24-hour period? **(F-25)**

2) At the date line, the calendar changes by one day. Travelers moving westward advance the calendar one day, while those moving eastward turn back the calendar one day.

What happens to the date as a traveler crosses the date line going west? East?

B. STUDYING THE HEAVENS

The unaided human eye, various kinds of telescopes, and sometimes photographs from space probes are used to study objects in space.

How do we find out about the universe?

1. Optical astronomy

a. The human eye

Astronomy can be done with the unaided human eye. Without binoculars or telescopes, we can see constellations, star clusters, nebulae, and galaxies.

What are some examples of constellations? Where is each located in the sky? **(F-26)**

What is some folklore about commonly known constellations?

b. The refracting telescope

A refracting telescope uses a convex lens to gather and focus starlight. Ordinary binoculars are a form of refracting telescope.

How is a refracting telescope constructed? **(F-27)**

How is a refracting telescope like the human eye?

c. The reflecting telescope

A reflecting telescope uses a curved mirror to gather and focus starlight. In general, reflecting telescopes are much larger than refracting telescopes.

How are reflecting telescopes constructed? **(F-28)**

What are the advantages of reflecting over refracting telescopes?

d. Advantages of optical telescopes

1) Optical telescopes have extended our vision into space since they gather more light than the eye and allow us to see dimmer objects.

2) Optical telescopes can better separate objects close together than our eyes can and allow us to see more detail on objects close to us. They form a bigger image of an object than our eyes alone can.

2. Other kinds of telescopes

a. Infrared telescope

An infrared telescope records heat energy from space. Since many kinds of infrared energy do not pass through Earth's atmosphere, infrared telescopes work best in space.

b. X-ray telescope

An X-ray telescope records X-rays from space. Since X-rays are absorbed by Earth's atmosphere, X-ray telescopes must be outside Earth's atmosphere.

c. Radio telescope

1) Radio telescopes collect and concentrate radio waves from space, extending our hearing into space. Since radio waves pass through Earth's atmosphere, radio telescopes can be located on Earth.

2) Radio telescopes have advantages over optical telescopes in that they can be used 24 hours a day, and radio waves are less affected by Earth's atmosphere and gas and dust in space.

3. Space probes

a. Satellite probes

Satellites launched into space send back photographs, television pictures, and data from the Moon, planets, and Sun. Data sent back include information on the Sun's sunspot cycles, and information about a planet's atmosphere or surface.

b. The Moon missions

The Moon is the only body in space that has been visited by humans. U.S.astronauts have walked on and explored the Moon. Instruments were left on the Moon to radio Moon data back to Earth.

What kinds of information about the Moon resulted from our visits there?

C. EARTH'S MOON

The Moon is Earth's nearest neighbor in space.

What is Earth's nearest neighbor like?

How far is the Moon from Earth?

1. General properties of the Moon

a. Size

With the possible exception of Pluto's Moon, Earth's Moon is closer in size to its planet than any other planet's Moon. Its diameter is more than one-fourth that of Earth's diameter.

How do the sizes of Earth and the Moon compare?

Why does the Moon look so large compared to other objects in our night sky?

b. Gravity

The Moon's surface gravity is about one-sixth of Earth's and, as such, it is too weak to hold either an atmosphere or water at its surface.

Why is the Moon's gravity so much less than Earth's gravity?

c. Orbit

As the Moon travels in its orbit around Earth, it always has the same side toward Earth. The plane of the Moon's orbit is not the same as the plane of Earth's orbit.

What would a simple scale model of the Moon-Earth system look like? **(F-29)**

How does the Moon travel relative to the Sun?

How are the Moon's periods of rotation and revolution related? **(F-30)**

d. Surface features

The absence of an atmosphere and water on the Moon creates surface features that are different from those on Earth. Moon rocks, for example, differ from Earth rocks in that Moon rocks contain no water. Moon rocks appear to be all igneous rocks.

What Moon features can be seen with the unaided eye? With field glasses or a telescope? **(F-31)**

How does the surface of the Moon's half we see differ from the half we do not see?

Why are rocks like limestone and shale apparently not present on the Moon?

2. Phases of the Moon

a. Causes of Moon phases

1) The Moon produces no light of its own, but must be seen by reflected light.

2) One half of the Moon is always lighted by the Sun as the Moon revolves around Earth. The amount of the lighted side observed from Earth determines the phase.

What are the phases of the Moon and how do they occur? **(F-32)**

b. Phases

At new Moon, the side facing Earth is dark and the Moon cannot be seen. At crescent phases, a sliver of the lighted half can be seen. At quarter phases, one half of the lighted side can be seen. At gibbous phases, all but a small part of the lighted side can be seen. At full Moon, all of the lighted side can be seen.

3. The Moon and eclipses

a. Eclipses of the Moon

Lunar eclipses occur when the Moon passes into Earth's total shadow and can be seen by anyone on the nighttime side of Earth. These occur only two or three times a year, and only at the full Moon phase.

How do lunar eclipses occur? **(F-33)**

Why is it that lunar eclipses do not occur at every full Moon? **(F-33)**

b. Eclipses of the Sun

Solar eclipses occur when the Moon comes between Earth and the Sun and the Moon's shadow reaches Earth. These can occur only at the new Moon phase and are rare at any one place on Earth.

How do solar eclipses occur? **(F-33)**

Why is it that solar eclipses do not occur at every new Moon?

4. The Moon and tides

Tides are caused by the gravitational attraction among Earth, the Moon, and the Sun.

The tides change as Earth rotates. High tides occur when a position on Earth faces directly toward or away from the Moon. About every 6.25 hours, the tides cycle from low to high, or from high to low.

Where is the Moon in relation to Earth during the tide cycle?

D. THE SUN AND OTHER STARS

Earth receives most of its energy from the Sun.

1. The Sun

What is the Sun like?

a. Size and distance from Earth

1) The Sun is many times larger than Earth, but, compared in size to other stars, the Sun is an average star.

How does the Sun's size compare to Earth's size?

2) The Sun is the closest star to Earth, one astronomical unit away.

What other units are used to measure distances in space?

b. Composition

The composition of the Sun can be determined with a spectroscope. Like most stars, the Sun is composed primarily of hydrogen and helium.

What is a spectroscope? How can it be used to tell what the Sun is made of? What else do spectroscopes tell us about stars?

c. Source of energy

The Sun's energy is the result of the conversion of hydrogen to helium through nuclear fusion.

What are the forms of energy Earth receives from the Sun? How much energy does Earth receive and what happens to it?

d. The Sun's layers

1) The photosphere is the bright yellow surface layer of the Sun.

2) The chromosphere is the red, lower part of the Sun's atmosphere.

3) The corona is the outermost part of the Sun's atmosphere. It is visible during solar eclipses.

How is it possible to know about the layers of the Sun's atmosphere?

e. Sunspots

Sunspots are dark spots on the photosphere which show that the Sun rotates on its axis. The number of sunspots is always changing and reaches a peak number about every 11 years. On Earth, sunspots cause auroras and magnetic storms.

How can sunspots be seen? **(F-34)**

What is the cause of sunspots?

What do sunspots show about the way the Sun rotates?

Do sunspots change in number from year to year? **(F-35)**

2. Other stars

What are stars other than the Sun like?

a. Star development

A star is formed from a cloud of dust and gas and changes over time as its hydrogen fuel is used up.

What does the Hertzsprung-Russell diagram tell us about stars? **(F-36)**

b. Kinds of stars

1) Young stars are dwarf stars.

2) Giant or supergiant red stars are stars that have used up much of their hydrogen fuel and have expanded.

What supergiant stars can be seen with the unaided eye?

3) White dwarf stars have used up most of their hydrogen fuel and have shrunk to small, dense stars.

4) Neutron stars are very dense white dwarf stars.

5) Pulsars are very rapidly spinning neutron stars.

6) Supernovas are thought to be supergiant stars that are exploding.

7) Black holes are thought to be collapsed stars which have such strong gravitational forces that their own light cannot escape from them.

c. Groups of stars

A galaxy is a system containing billions of stars. Our Sun belongs to the Milky Way galaxy.

What are the shapes of galaxies?

Which galaxy is visible to the unaided eye?

Where in the "Milky Way" is our solar system located? What is the shape of the "Milky Way" galaxy? **(F-37)**

d. Distances between stars

The distances between stars are vast. These, and other distances in space, are measured by the unit, light-year.

How far away are the nearest stars in kilometers? In light-years? How long would it take to travel to the nearest stars? What limits do these distances impose upon us?

E. THE SOLAR SYSTEM

The solar system consists of the Sun, and the planets and various other bodies which revolve around the Sun.

What is the solar system like?

1. The Sun's location in the solar system

The Sun is located near the center of the solar system. The planets revolve around the Sun in elliptical orbits.

How far is the Sun from each planet? **(F-38)**

2. The planets

There are nine known planets in the solar system. Each planet has its own unique characteristics. Earth is apparently the only planet that supports life. The inner planets are solid bodies, while most of the outer planets are composed of gas. Many of the planets have moons. The number of moons revolving around a planet varies with the planet.

How do the planets differ from stars in appearance?

How do the sizes of the planets compare to one another? **(F-39)**

What are the special characteristics of each planet?

What are the characteristics of the different moons?

3. Other solar system objects

a. Asteroids

Asteroids are small planet-like bodies, most of which orbit the Sun between the inner and outer planets. They are composed of matter similar to the matter of planets.

b. Meteors

Meteors are rock fragments traveling in space that enter and heat in Earth's atmosphere, producing light. Meteor showers occur when Earth crosses the orbit of a meteor swarm. These occur regularly each year.

How are meteors observed? How big are "typical" meteors? How far away from the observer are they?

When do meteor showers occur?

c. Meteorites

Meteorites are the parts of meteors that reach Earth's surface.

d. Comets

Comets are unconsolidated masses of rock, ice, dust, and gas ("dirty snowballs") that travel around the Sun in highly elliptical orbits. When near the Sun, comets are seen as a glowing head and a long bright tail. The tail always points away from the Sun.

Halley's comet returns every 76 years. Upon its return, it is visible to the unaided eye in the nighttime sky.

Concepts and Understandings	Questions and Activities

A. FLIGHT IN AIR

Flight in air was the precursor to flight in space. The knowledge gained from flying in the atmosphere helped humans achieve flight in space.

There are two types of flight in air: lighter-than-air flight and heavier-than-air flight.

1. Lighter-than-air flight

How do lighter-than-air aircraft function?

a. Characteristics of air that affect lighter-than-air flight

How is air like water?

1) Air is a fluid, as is water.

2) The density of air decreases with altitude.

3) An object less dense than air at Earth's surface will rise until its density is equal to the density of the air surrounding it. Then it will float.

4) An object slightly more dense than the air surrounding it will sink. As the object sinks, the density of the air surrounding it increases. The object will float when its density equals the density of the surrounding air.

b. Lighter-than-air aircraft

When does a balloon rise? Sink? Float?

Is hot air lighter than cold air? **(F-40)**

1) Balloons rise because they contain a gas that is lighter than the air in the atmosphere. Modern balloons are filled with air that is warmer than the air in the atmosphere, and, therefore, lighter.

A balloon's direction is dependent upon the direction of the wind; horizontal motions cannot be controlled.

How are the motions of balloons controlled?

2) Airships (also called dirigibles) are rigid balloons with streamlined shapes and are filled with the gas, helium.

What are airships used for today?

Why did early airships use hydrogen when helium was so much safer? What happened to the Hindenburg, an early airship?

Airships have engines which allow them to be moved horizontally and to be steered.

2. Heavier-than-air flight

How do heavier-than-air aircraft function?

a. Forces affecting heavier-than-air flight

What is lift? How is lift produced? **(F-41)**

1) Lift is the upward force that results from air moving around an object. Lift occurs when air is moving faster on one side of an object. This faster moving air exerts less pressure.

2) Weight results from the downward pull of gravity.

3) Thrust is the force that pulls or pushes an object forward.

4) Drag is the resistance of the air to an object moving through it.

5) Lift and weight are opposite forces, as are thrust and drag.

Can we demonstrate how lift overcomes weight? **(F-42)**

b. Achieving heavier-than-air flight

1) Airplane wings are designed to provide lift. Air flows faster (and exerts less pressure) across the top of the wings than across the bottom. The airplane rises. As the air moves faster past the wings, the airplane rises more (lift increases).

2) For an airplane to rise, the force of lift has to be greater than the airplane's weight.

Are lift and weight balanced or unbalanced in steady, level flight? On takeoff? On landing?*

3) For an airplane to move forward through the air, the thrust provided by the plane must be greater than the drag caused by the resistance of the air.

Are thrust and drag balanced or unbalanced in steady, level flight? On takeoff? On landing?*

4) Drag is reduced when air can flow smoothly around an object. An airplane's shape is designed to reduce drag.

How is the nose of an airplane shaped? Its body? Its wings? How do these shapes reduce drag? How does ice or snow on a wing affect drag? Thrust?

c. Heavier-than-air aircraft

1) Gliders are aircraft without engines and must be launched into the air. One way a glider can be launched is by towing it with an airplane.

Once in the air, gravity provides the thrust needed for the glider's wings to have lift. Gliders use areas of rising warm air, called thermals, to increase their altitude.

2) An airplane has an engine which provides the thrust to propel the plane through the air. An airplane engine may be a gasoline engine or a jet engine.

A gasoline engine drives a propeller, while a jet engine exhausts a rapid flow of heated air and gases. Both engines produce thrust as a result of the law of action and reaction.**

To become airborne, an airplane must gain enough speed for the lift of its wings to overcome its weight. As an airplane moves down a runway, its engine increases the airplane's speed and therefore its lift.**

How does a propeller provide thrust? **(F-43)** What is the effect of the speed of the propeller on the speed of the airplane?

How is an airplane gasoline engine like an automobile engine or lawn mower engine?

How do jet engines work? **(F-44)**

What is the law of action and reaction? In a jet engine, what is the action force? The reaction force?

3) A helicopter provides lift and thrust by means of rotating wings (blades) called the rotor. A helicopter

How does the rotor provide lift for a helicopter? **(F-45, 46)**

** For more on the law of action and reaction and on acceleration, see Block G, *Energy and Motion*.

* To reinforce the concepts in Block G, *Energy and Motion*, these forces can be studied in terms of balanced and unbalanced forces.

has a second set of rotating wings at the tail which turn in the opposite direction from the main rotor and prevent the helicopter body from turning.

A helicopter can fly in any direction, including straight up and down, and it can also hover in one place.

What other ways could be used to stabilize a helicopter in flight?

Why doesn't a helicopter require a runway?

4) Missiles are pilotless airplanes with built-in navigation systems that guide them toward their targets.

d. Controlling heavier-than-air flight

In flight, an aircraft has three basic motions which must be controlled.

How can the flight of a paper airplane be controlled? **(F-47)**

1) Pitch is the up and down movement of an aircraft's nose. It is controlled by hinged flaps, called elevators, in the horizontal part of the aircraft's tail. Raising the elevators pushes the nose up and causes the aircraft to climb. Lowering the elevators pushes the nose down and causes the aircraft to dive.

What is the function of elevators? **(F-48)**

2) Roll is the up and down motion of the aircraft's wing tips. It is controlled by movable flaps, called ailerons, on the wings. Raising the aileron causes the wing to go down while lowering it brings the wing up. Moving the ailerons on opposite wings in opposite directions at the same time causes the aircraft to tilt to the left or to the right.

How do the ailerons work? **(F-49)**

What is a barrel roll?

3) Yaw is the turning motion of an aircraft. It is controlled by a vertical fin, called the rudder, in the tail of the aircraft. Pushing the rudder to the left causes the aircraft to turn to the left, while pushing it to the right results in a right turn.

What is the function of a rudder? **(F-48)**

3. Navigation in air

How do pilots navigate?

a. Methods of navigation

1) Pilotage is navigation by visible landmarks. The landmarks can be previously known or recognized from a map.

What landmarks in the local area could a pilot use for navigation? **(F-50)**

Pilotage has limited use over poorly mapped country, over bodies of water, during the night, or when visibility is poor. Whenever possible, pilots use pilotage with other methods of navigation.

2) Dead reckoning locates a plane's position by finding the direction and distance the plane has flown from a known position. Flight instruments are used in dead reckoning.

What method of navigation did Lindbergh use in crossing the Atlantic?

Dead reckoning requires a knowledge of wind speed and wind direction as well as the airspeed and direction of the plane.

What effect would crosswinds have on an airplane's direction of flight?

What would be the effect of a headwind or a tailwind?

Dead reckoning can be used over poorly mapped country, over bodies of water, during the night, or when visibility is poor.

3) Radio navigation uses radio signals to locate an airplane. If the position of a radio transmitter is known, a plane's position can be found by simply locating the direction from which the radio signal comes to the plane.

Signals from several transmitters, such as radio satellites circling Earth, can be used by planes to find instantly their exact position.

Radio navigation methods make it possible to fly and land an airplane without being able to see the ground.

4) Weather forecasts, radar, and electronic equipment, including computers, provide additional information for navigation.

Why is it important to know your exact position, especially near busy airports?

Why are weather forecasts important in navigation?

b. Flight instruments which aid navigation

How has technology extended the senses of a pilot?

What is it like being a pilot? (Invite a pilot to speak to the class.)

1) The altimeter tells the height, or altitude, of the aircraft above sea level. Altimeters work by measuring air pressure. Air pressure decreases as altitude increases.

2) The airspeed indicator shows the approximate speed of the aircraft through the air.

The airspeed indicator works by reacting to the air pressure caused by the aircraft moving through the air. This air pressure increases as the aircraft's speed increases.

3) The magnetic compass reacts to Earth's magnetic field and points in the direction of the magnetic north pole.

A correction for the difference between magnetic north and true north must be made on a compass. The amount of the correction depends upon location.

4) The heading indicator is a kind of gyroscope. It is a wheel, or disk, that, once spinning, resists changes in direction.

The heading indicator provides additional information about direction. It supplements the magnetic compass because it is not affected by the factors that cause errors in compass readings.

How does a gyroscope work? **(F-51)**

B. FLIGHT IN SPACE

Humans are just learning how to fly and live in space. Space flight is an active area of scientific and technological research and development.

How is space flight different from flight in air? What forces affect space flight?

1. Getting into space

a. Forces affecting space flight

1) To achieve space flight, a space vehicle must have enough thrust to overcome the force of Earth's gravity* and the drag of the air the vehicle is moving through.

Thrust is an opposite force to gravity and drag.

2) The thrust of the vehicle must also act on the vehicle's inertia,* in this case, its tendency to remain at rest.

3) The force of gravity decreases as the distance from Earth increases. The force of gravity becomes almost nothing at a distance of a few million kilometers into space.

4) Once outside Earth's atmosphere, drag becomes insignificant.

5) In space, the thrust required to keep the space vehicle moving becomes insignificant since gravity and drag are almost nothing. Inertia, in this case, the tendency to remain in motion, keeps the vehicle moving.

6) To reduce the amount of thrust required to launch a space vehicle, most space vehicles are launched toward the east, taking advantage of Earth's rotation in that direction.**

What is thrust and how is it measured? **(T-52)**

Why does it take more thrust for a rocket to get into space than for an airplane to fly through the atmosphere?

What is inertia? **(T-53)** What determines how much inertia an object has?

How does inertia relate to rocket thrust? **(T-53)**

b. Acceleration

A space vehicle accelerates after launch. The rate of acceleration of an unmanned space vehicle is limited by the stress the vehicle's structure can withstand. The rate of acceleration of a manned space vehicle is limited by the stress that a human can withstand and survive.

How does acceleration affect getting into space?

c. Achieving closed space orbit

1) When a space vehicle goes into Earth orbit, it revolves around Earth. The interaction of gravity and the vehicle's inertia result in revolution. To achieve orbit, gravity and orbital speed must be balanced.

2) The speed a space vehicle needs to go into orbit depends upon the altitude of the orbit. As the altitude increases, the speed needed to go into orbit decreases.

3) The greater the altitude of the orbit, the longer the time it takes for the space vehicle to travel once around the orbit.

4) A space vehicle in orbit is in free fall. The spacecraft and all the objects in it appear to be weightless.

What factors affect a space orbit?

How can we demonstrate a closed orbit? **(T-54)**

What is the relationship between gravity and orbital altitude? **(T-54)**

What conditions must be met for an object to go into orbit around Earth?

Why are the objects in the spacecraft essentially weightless?

How can we demonstrate weightlessness? **(T-55)**

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* For a more indepth treatment of both gravity and inertia, see Block G, *Energy and Motion*.

** Some space vehicles, however, are launched into polar orbits.

5) Spacecraft that orbit Earth at the same rate as Earth turns will remain above the same point on the surface. Such spacecraft are said to be geostationary or in geosynchronous orbit.

What is the orbital period of a spacecraft in geostationary orbit?

d. Achieving open orbit or Earth escape

1) The escape velocity is the launch speed needed by a space vehicle to escape completely from Earth's gravity. It is more than the velocity needed for Earth orbit.

How can we demonstrate escape velocity? **(F-56)**

How does the amount of energy needed to obtain Earth orbit compare with the amount needed for escape?

2) A spacecraft that escapes Earth's gravity will go into orbit around the Sun unless it comes into the gravity of another solar system object or unless additional thrust is supplied.

Is the escape velocity the same for all space vehicles? How is escape velocity a function of mass? **(F-56)**

3) The calculation of a flight path to other solar system objects is complex.

Why is the calculation of a flight path complex?

2. Returning to Earth

How is a spacecraft returned to Earth safely?

a. Re-entry

1) Re-entry of a spacecraft into Earth's atmosphere occurs when the spacecraft's velocity falls below the amount needed to keep it in orbit. Retrorockets slow the spacecraft and cause it to move toward Earth.

What force brings the spacecraft back toward Earth?

2) As the spacecraft enters Earth's atmosphere, friction with the air causes intense heat. A heat shield prevents the spacecraft from burning up.

How does a heat shield work? **(F-57)**

3) The angle at which the spacecraft enters Earth's atmosphere is critical. If the angle of re-entry is too shallow, the spacecraft will bounce back into space. If the angle of re-entry is too steep, the heat shield will burn away and/or the crew will not survive the stresses that result.

b. Recovery

1) Spacecraft that free fall through the atmosphere must be slowed by parachutes or by rockets before striking Earth's surface. These "soft landings" usually occur in water.

2) Some spacecraft can be landed like gliders. The space shuttle, for example, is controlled like an aircraft.

How is the space shuttle like an aircraft?

3. Spacecraft

What are the necessary parts of a spacecraft?

a. The thruster

1) Like airplane engines, rockets provide thrust (as a result of the law of action and reaction) to get a spacecraft aloft.

How are jet engines and rocket engines alike and how are they different?

2) Unlike airplanes, spacecraft leave Earth's atmo-

sphere and, therefore, their rockets must carry with them the oxygen needed to burn their fuel.

3) Rockets have stages which are dropped off as their fuel is used up. As the fuel is used and the stages drop off, the rocket becomes lighter and can rise faster.

b. The payload

The spacecraft carries a payload which is the portion of the craft that carries the passengers and/or instruments. The payload is usually a separate module, comprising a very small portion of the total weight of the spacecraft.

c. Spacecraft systems

What kinds of systems are needed for a spacecraft to function and to keep humans alive in space?

1) The airframe or structural system is the framework of the spacecraft. Since it supports and protects all of the other systems, it must be both lightweight and able to withstand the stress of flight.

How large is the airframe of a typical launch vehicle?

2) All spacecraft need an electrical power supply, the sources of which include batteries, solar cells, and fuel cells.

3) The propulsion system consists of small rockets that control the pitch, roll, and yaw of a spacecraft, and allow it to change orbits, speed up, and slow down.

Is much force needed to maneuver a weightless spacecraft in space?

4) The guidance system steers the spacecraft and controls its velocity. The basis of the guidance system within the spacecraft is an inertial platform. This consists of several spinning gyroscopes which make exact measurements of change in the spacecraft's position and velocity. A computer collects all of the data on position and velocity and makes corrections for any changes that have occurred.

How is the guidance system of a spacecraft similar to the navigation instruments of aircraft?

What methods of navigation are used in spacecraft? How do these methods compare with those used in aircraft?

A worldwide network of tracking stations keeps Earth orbit spacecraft informed of their exact position relative to Earth. Spacecraft in Earth-escape trajectories use very bright stars or groups of stars to guide them.

How are spacecraft in orbit tracked?

5) The life-support system provides an environment in which a human can travel in space and survive.

How is the environment of space different from Earth's environment?

(a) Air pressure is provided.

What must a life-support system be able to do?

(b) Oxygen is supplied to the spacecraft atmosphere while water vapor and carbon dioxide are removed.

(c) Comfortable working temperatures and humidities are maintained.

Why is humidity important?

(d) Human wastes are safely collected.

(e) Necessary food and water are carried.

(f) Special couches protect space travelers from the stresses of launch and re-entry.

(g) Special exercises are used to keep the muscles of space travelers working properly in a weightless state.

What is it like to be weightless?

What kinds of exercises could space travelers do? **(F-58)**

(h) Special shields protect space travelers from harmful radiations found in space.

What kinds of radiations occur in space that do not reach Earth's surface?

4. Space programs

How long has the United States had a space program? What are its major achievements?

a. Unmanned programs

Unmanned spacecraft have now been sent to study the Sun, the Moon, and all of the known planets except Pluto.

To reach the outer portions of the solar system, the gravity of one planet is used to propel a spacecraft on to the next.

b. Astronaut programs

What special provisions must be made to enable humans to travel in space?

Early astronaut programs tested human ability to withstand space launch, weightlessness, and Earth reentry.

What kinds of space vehicles carried astronauts into space?

Highlights of later space programs include walks in space, the landing of humans on the Moon and their safe return to Earth, a long-term space laboratory, and reusable spacecraft (the space shuttle).

Which astronauts have been in space? What did each astronaut's mission achieve? **(F-59)**

What hazards did each mission encounter? How did the hazards compare with the hazards of Earth exploration?

Astronauts are carefully chosen and must undergo a rigorous training program to enable them to perform their mission specialities.

What is it like to walk and work on the Moon? **(F-60)**

What does an astronaut need to walk in space? **(F-61)**

What kinds of projects were carried out on Skylab, the space laboratory? On the space shuttle?

What are the advantages of a reusable spacecraft?

c. Benefits of the space programs

What are the benefits of the space programs?

1) Information about Earth

(a) Weather satellites provide weather data from every part of Earth's surface.

What are some areas of Earth's surface where there are no ground weather stations?

(b) Communications satellites receive and send out television, telephone, and other signals, linking almost every country in the world.

Why are many satellites in geostationary orbits?

What kinds of events are televised around the world as they happen?

(c) Earth survey satellites provide information on Earth resources, agricultural crops, air pollution, and many other surface occurrences. These satellites have allowed detailed mapping of all parts of Earth's surface.

What are some other uses of Earth survey satellites?

2) Information from beyond Earth

(a) Some satellites are orbiting observatories that gather data about the universe. Use of these satellites has resulted in many new discoveries.

What are some of these discoveries?

(b) Other spacecraft visit other solar system bodies and send back information about them.

3) Spin-offs

(a) The development of computers was speeded by the needs of the space programs.

(b) Some products developed for use in the space programs have found uses in medicine.

(c) Technology developed for the space programs is continuously being adapted for our everyday use.

What is a spin-off? What are some examples that can be displayed in class?

How are the newer artificial limbs a spin-off of the space programs?

What is Tang? Velcro? Teflon? Corning Ware? Have you ever used them? How?

How are insulation tiles a spin-off? Miniaturization?

d. Burdens of the space programs

What are the burdens of the space programs?

1) The ability to put nuclear weapons into space may increase the danger of nuclear war and carries with it the greater responsibility of avoiding nuclear war.

2) The financial costs of space programs may result in underfunding of other government programs.

e. Future space programs

What is our future in space? **(F-62)**

1) Earth orbit satellites and space probes to other solar system bodies can continue to provide important new discoveries and information.

2) An orbiting space station may be our next major space effort. The space station could be used to study space manufacturing.

3) Space factories could use the weightless, airless conditions of space to manufacture many products that cannot be manufactured on Earth.

Why could extremely pure products be manufactured in space? Why might alloys be easier to manufacture in space?

4) Many other space programs are possible, including a Moon base and space colonies, but they will probably not occur in the near future. For now, humans need Earth as their home base.

How would you plan a trip to another planet? **(F-63)**

What kinds of space programs would you like to see in the future?

What are the advantages of a Moon base or space colony?

What conditions would have to be met before a Moon base or space colony could operate?

APPENDIX — LEARNING ACTIVITIES

NOTE TO THE TEACHER

The National Aeronautics and Space Administration (NASA) has many educational and informational publications that can be used in teaching the activities which follow. For a list of publications and information on how to order them, contact:

Education Officer
NASA Goddard Space Flight Center
Greenbelt, MD 20771

Be sure to order the publications list early in the school year, and to allow adequate time both for receiving the list and ordering from it. It may take six to eight weeks to receive publications once they have been ordered.

Periodicals which may aid in teaching the activities include the following:

The Universe in the Classroom: A Newsletter on Teaching Astronomy, Astronomical Society of the Pacific (1290 24th Avenue, San Francisco, CA 94122, free)

Sky and Telescope, Sky Publishing Corporation (49 Bay State Road, Cambridge, MA 02238, subscription fee)

Space World, Palmer Publications, Inc. (318 Main Street, Amherst, WI 54406, subscription fee)

F-1. WHERE IS EARTH'S AXIS OF ROTATION?

(1,2,20)

MATERIALS:

model globe or any round sphere (styrofoam or rubber ball, orange, baseball, basketball)
marking pens
stick or pencil (optional)

PROCEDURE:

(1) Outline the continents and the North and South Poles on the sphere.
(2) Place one finger on each of the poles and spin (rotate) the sphere around the poles in a counter-clockwise direction as viewed from above the North Pole. (If a sphere is used that would allow a stick or pencil to penetrate it, push the stick or pencil through the poles.)
(3) Diagram your setup in your notebook. Draw a line through the sphere to represent the axis of rotation. Indicate the direction of rotation of the sphere.

RESULTS:

Earth's axis of rotation is around a line extending through its poles.

F-2. HOW CAN WE DETERMINE THE APPARENT MOVEMENT OF THE SUN ACROSS THE SKY DURING THE COURSE OF A DAY?

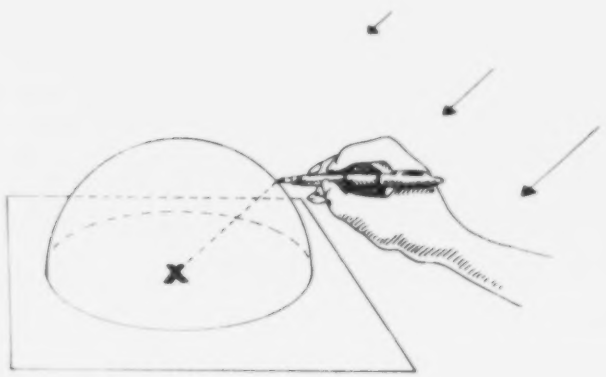
(20,1,2)

MATERIALS:

a transparent dome
a piece of heavy cardboard large enough to place the dome on
marking pen
compass
protractor
masking tape

PROCEDURE:

(1) On a sunny day, take the materials outside.
(2) Place an "X" in the center of the cardboard.
(3) Tape the transparent dome on the cardboard, centering the "X" under the middle of the dome.
(4) Indicate the compass directions on the cardboard. Orient the cardboard and dome according to the compass directions.
(5) About once every hour hold the point of the pen just above the outside of the dome so that the shadow of the point falls directly on the middle of the "X" under the dome. Mark the point where the pen is held on the outside of the dome. (Other students may do this step for you during their science class.)
(6) When all the points have been placed on the dome, draw an arc through the points. What does this arc represent?
(7) Plan how you would use the protractor to determine the number of degrees that the Sun appears to move across the sky every hour. Check your plan with your teacher and revise it if necessary. Determine the number of degrees. What is your measurement?
(8) What is the exact direction of sunrise and sunset for this apparent path of the Sun?
(9) How does the apparent path of the Sun change with the seasons? Plan how you could solve this problem and carry out your plan. Then answer the following questions:
   (a) How does the noontime altitude of the Sun vary with the seasons?
   (b) How does the length of the daylight period vary with the seasons?
   (c) How does the direction of sunrise and sunset vary with the seasons?



RESULTS:

The daily apparent path of the Sun through the sky is an arc which varies with the seasons. The Sun apparently moves through the sky at a rate of 15° every hour. The altitude of the Sun is highest on the summer solstice and lowest on the winter solstice. The daylight period is longest on the summer solstice and shortest on the winter solstice.

Students should be given an opportunity to plan how they would carry out the longer-term investigation based on their one-day investigation. The teacher may need to assist with the planning.

F-3. DO THE STARS APPEAR TO MOVE ACROSS THE NIGHTTIME SKY?

(8,10,14)

PART A

MATERIALS:

paper and pencil

PROCEDURE:

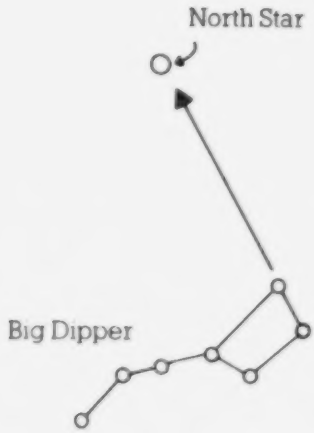
(1) How could you determine if the stars appear to move across the nighttime sky? With your teacher, plan how you would solve this problem. Be sure to include some Earth reference points (like the horizon) in your plan.
(2) Carry out your plan. What constellation did you choose to observe? What reference points did you choose?
(3) Do the stars appear to move across the nighttime sky? If they do, what is the direction of their motion? In what direction were you facing when you observed them?

RESULTS:

A student plan might look like the following.

(1) At home early on a cloudless night, I will go outdoors and face north. I will locate the Big Dipper (or another convenient constellation for the season, in which case the student may face south) from information my teacher has given me.
(2) During the next day, I will face in the same direction and sketch the horizon below the Big Dipper.
(3) In the evening of this next day, I will plot the position of my constellation every two or three hours.

Students should be able to see the apparent diurnal motion of the stars. If they face north, this motion will be counterclockwise (west to east) around the extended northern axis. If they face south, it will be clockwise (east to west).



PART B (optional)

MATERIALS:

a camera that can take time exposures
a tripod or other setup to aim the camera without moving it over time
sensitive film (such as Kodak Tri-X)

PROCEDURE:

(1) Aim the camera at the North Star after dark. (Your teacher can show you how to locate the North Star.)
(2) Leave the shutter open for two or more hours.
(3) Have the film developed.
(4) Based on your photograph, do the stars appear to move across the sky? If they do, how do they move?

RESULTS:

Star trails show that the stars appear to move around a fixed point (the North Star).

F-4. HOW DOES A FOUCAULT PENDULUM SHOW THAT EARTH ROTATES?

(18,20,1)

PART A

MATERIALS:

swivel stool (a lab stool)
a string or wire attached to a weight (sinker or nut)

PROCEDURE:

(1) Have one student sit on the swivel stool. Another student should stand on a desk near the stool and swing the string with the weight attached back and forth (in one direction only) over the first student's head.

(2) Have the student on the stool slowly rotate counterclockwise while looking up at the weight. This student should continually try to point in the direction the pendulum is swinging.

(3) Have other students take turns at the activity so they can experience it first hand. (Since students will be standing on desks, you will probably not want to have more than one or two setups for this.)

RESULTS:

It is difficult to keep track of the apparent change in the direction of the pendulum's swing while you are rotating. But it is clear that the weight is still swinging in the same true direction. This same experience is true for a Foucault pendulum.

PART B

MATERIALS:

a lazy Susan or a lab stool
string with a weight attached
(sinker or nut)

PROCEDURE:

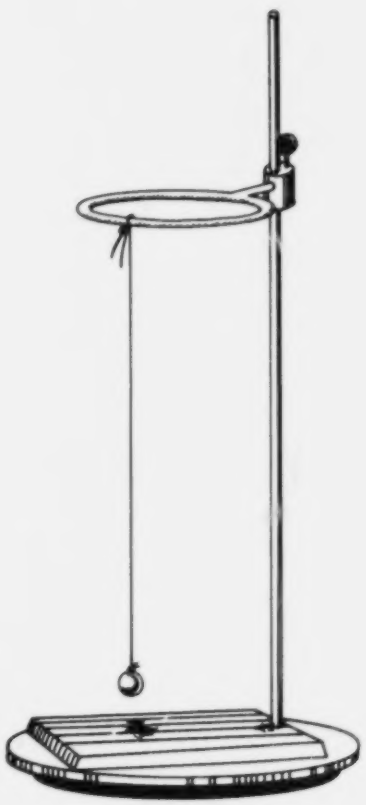
(1) Working in a small group, draw a sketch of Earth's continents in the Northern Hemisphere as seen from the North Pole. (Your teacher may supply this.) Place this sketch on the lazy Susan.

(2) Suspend the string and weight over the lazy Susan and swing it back and forth in one direction only.

(3) At the same time, slowly turn the lazy Susan counterclockwise.

(4) Stop after the lazy Susan has moved a quarter turn. Over what part of Earth does the pendulum appear to be swinging?

(5) Continue slowly turning the lazy Susan another quarter turn and answering the question in (4) until the lazy Susan is back in its original position.



RESULTS:

The pendulum "appears" to be moving over different parts of Earth. But it has been swinging in the same true direction, just as a Foucault pendulum on Earth's surface does.

F-5. HOW DO OBJECTS MOVING OVER THE SURFACE OF EARTH APPEAR TO BE DEFLECTED?

(18,20)

MATERIALS:

a lazy Susan or lab stool
paper towel
a marble
water

PROCEDURE:

(1) Working in small groups, cut a dry paper towel to the shape of the lazy Susan. Tape the paper towel to the lazy Susan.
(2) Slowly turn the lazy Susan counterclockwise and roll a wet marble across the surface. What is the path of the marble?
(3) Now ask one member of your group to sit directly across from where the marble will be released and to concentrate on the movement of just the marble. Repeat (2). What is the path of the marble? Take turns sitting across from the released marble and observing.
(4) Which path is the "true" path of the marble? Which is its "apparent" path? How do you know?

RESULTS:

The marble's true movement is straight, although the apparent path (the water trail on the paper towel) is curved, just as objects moving in a true path across Earth's surface would appear to follow a curved path.

F-6. WHAT PART OF EARTH IS IN DARKNESS AT ANY GIVEN TIME?

(18,1,20)

MATERIALS:

light source (a projector or lamp)
sphere (ball, orange, etc.)
marking pen

PROCEDURE:

(1) Darken the classroom. Turn on the light source.
(2) Have a student hold up a sphere a few feet from the light source. Ask another student to mark on the sphere the portion of the sphere lighted by the light source.
(3) Ask a student to place an "X" on the sphere to represent the school's location.
(4) Ask the student holding the sphere to rotate it counterclockwise. When is the school (the "X") experiencing night? Day?
(5) In which position is the school ("X") experiencing dawn? Noon? Dusk? Midnight?

RESULTS:

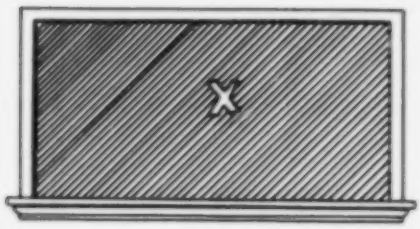
Half of Earth is lighted at any one time. Noon occurs when the Sun's rays are most direct at a location. Dawn and the a.m. hours occur before noon and dusk and the p.m. hours occur after noon. Midnight occurs when the location of the "X" is directly opposite the Sun on the far side.

F-7. WHAT IS PARALLAX DISPLACEMENT?

(1,2,14)

MATERIALS:

chalkboard with an "X" drawn on it



PROCEDURE:

(1) Hold out your arm in front of you with your index finger held up. Close one eye and line your finger up with the "X" on the chalkboard.

(2) Now switch closed eyes. What happened to your finger's position in relation to the "X"?

(3) Now hold your finger closer to your eye and repeat (1) and (2). Is there a difference in results? If so, what is it?

RESULTS:

The finger appears to hop off the "X" when the eyes are switched. When the finger and "X" are aligned with one eye and then the eyes are switched, you are actually viewing the finger against the background of the "X" from a different position. The finger's position in relation to the "X" changes. This same phenomenon occurs as Earth rotates and near stars are viewed against the background of more distant stars.

F-8. WHAT ARE SOME CONSTELLATIONS THAT CAN BE SEEN DURING THE VARIOUS SEASONS?

(18,1,20)

MATERIALS:

pictures of key seasonal constellations drawn on construction paper

a large and a smaller sphere (beach ball and tennis ball) to represent the Sun and Earth

PROCEDURE:

(1) Place the constellations on the walls of the classroom according to their relative positions on the celestial sphere (see diagram).

(2) Place the "Sun" (larger sphere) in the center of the classroom.

(3) Draw an "X" representing your location on Earth (smaller sphere).

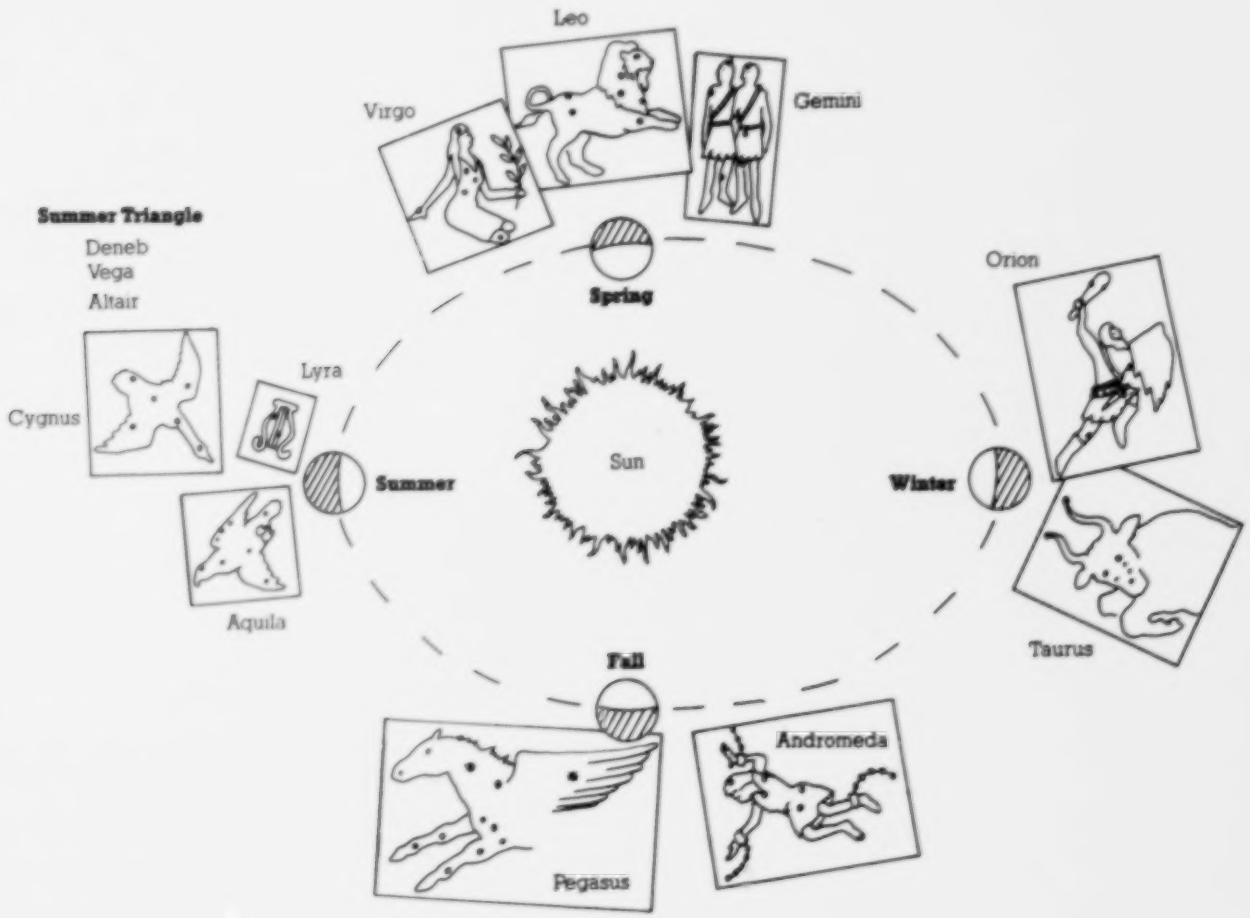
(4) Slowly revolve Earth around the Sun, always keeping Earth turned so that your location is opposite the Sun. Why should Earth be held this way?

(5) As you start revolving Earth, which constellations are visible? Invisible? Why?

(6) What happens as Earth continues to revolve until it returns to its original position?

RESULTS:

Some constellations are not visible during some portions of Earth's revolution. The visibility of constellations can be matched to the seasons, as shown in the diagram.



F-9. WHAT CAUSES THE CHANGING SEASONS?

(18,1,22,20)

MATERIALS:

light source
a globe that can be tilted
clay

PROCEDURE:

(1) Let a small piece of clay represent an observer and place it on the globe in the area that represents where we live.

(2) Darken the room and place a light source in a central area where the globe can be revolved around the light source.

(3) Place the globe in each of the major seasonal positions (winter, summer, equinoxes). Don't tilt the globe. Rotate the globe in each position. For each seasonal position, determine the relative length of daylight where the observer is located. Place your data in the correct location in the table provided.

(4) Now hold the globe at an angle of about 23 1/2° from the vertical. Repeat (3).

(5) Hold the globe at an angle greater than 23 1/2° from the vertical. Repeat (3).

(6) Answer the following questions:

(a) When the globe has no tilt, how does the length of daylight vary with the seasons? When it is tilted 23 1/2° degrees? When it is tilted more than 23 1/2°?

(b) How does the tilt of the globe affect the length of daylight over the seasons?

(7) Now place the observer within the Arctic Circle and repeat (3) with the globe tilted 23 1/2°. How has the relative length of daylight changed for each season compared to the observer at our location (with the globe tilted 23 1/2°)?

DATA TABLE

	No tilt	Tilted 23 1/2°	Tilted more than 23 1/2°
Summer			
Fall			
Winter			
Spring			

RESULTS:

With the globe tilted at a great angle, the changes in length of daylight are more pronounced across the seasons. As an observer moves to greater latitudes, the daylight changes also become more pronounced.

F-10. WHAT HAPPENS TO THE SEASONS AND DAYLIGHT PERIOD AS EARTH MOVES ALONG ITS ORBIT?

(18, 20, 17)

MATERIALS:

globe
floor lamp with a bright bulb

ADVANCE PREPARATION:

The day before this game is actually played, acquaint students with the rules and conduct a short practice session. This should serve as motivation for students to study the concepts involved. You may want to provide some prizes or other incentives (no homework, extra credit) for the winners.

PROCEDURE:

(1) Place the floor lamp in the center of the room to represent the Sun.
(2) With your classmates, form a circle around the lamp to represent Earth's orbit.
(3) Start passing the globe around the circle to represent Earth's movement along its orbit. When you have the globe, you are responsible for rotating and tilting it properly.
(4) Stop the globe only when your teacher asks a question. The student holding the globe must answer the question. If the question is answered correctly, the student continues to play. If the question is not answered correctly, the student sits down. Occasionally, your teacher will ask a "free" question that may be answered by a seated student. A correct answer allows the student to re-enter the game. All students who remain standing at the end of the session are winners.
(5) Occasionally, your teacher will instruct you to move around the circle to a new position.

SAMPLE QUESTIONS:

At this point in Earth's orbit and rotation:
(1) What is the length of daylight at the equator?
(2) What is happening to the length of daylight?
(3) What location on Earth is receiving the most direct rays of the Sun?
(4) What season (month) is it?
(5) Stop the globe at the summer (winter) solstice. The fall (spring) equinox.

F-11. WHAT CAUSES EARTH TO CHANGE DISTANCE FROM THE SUN?

(18,20)

MATERIALS:

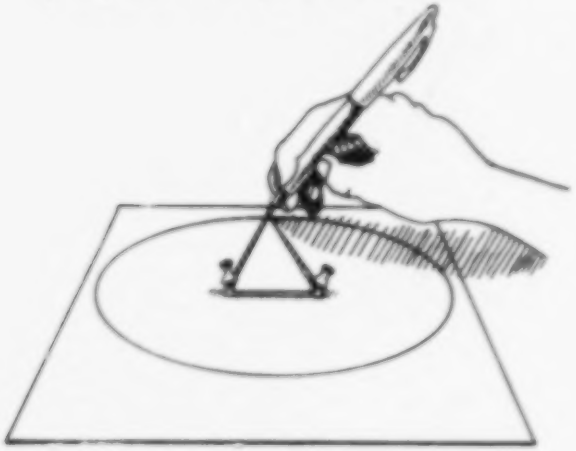
a sheet of paper
a piece of cardboard large enough to hold the paper
two thumbtacks
string

PROCEDURE:

(1) Tape the sheet of paper on the cardboard.
(2) Place the thumbtacks about 3 cm apart in the middle of the paper.
(3) Cut a piece of string approximately 20 cm long and tie the ends of the string together to make a loop.
(4) Place the loop around the tacks. Holding the pencil upright, place the tip of the pencil inside the loop and pull the string taut (see diagram).
(5) Keeping a constant tension against the looped string, move the pencil around the inside of the loop to trace a line.
(6) Remove one of the tacks. The remaining tack represents the Sun and the pencil line represents Earth's orbit. What is the shape of Earth's orbit?

(7) Is this shape the same as a circle? Use the remaining tack and the looped string to draw a circle. How does the shape of Earth's orbit compare to the circle?

(8) How could you make the line drawn by the pencil look more like an ellipse? State your hypothesis and your plan to solve this problem, then carry out your plan. What is your conclusion?



RESULTS:

The shape of Earth's orbit is actually an ellipse, but it is very close to a circle. Students may not be able to discriminate between the two shapes drawn. As the distance between the tacks increases, the shape of the line drawn becomes more elliptical. Interested students can be encouraged to draw the shapes of other planets' orbits to scale.

F-12. HOW WOULD A SHADOW OF A DISK-SHAPED EARTH APPEAR?

(18,9,20)

MATERIALS:

a piece of stiff paper or cardboard
scissors
light source
globe

PROCEDURE:

(1) Does a circle always produce a round shadow? State a hypothesis regarding this problem.

(2) Cut the stiff paper or cardboard into the shape of a circle.

(3) Turn on the light source and darken the room. Turn the circle different ways in the light source and observe the shadows the circle projects on the globe. Record the shapes of these shadows.

(4) Was your hypothesis correct? State your conclusion from this investigation.

RESULTS:

A disk-shaped Earth would not always produce a round shadow.

F-13. WHAT DOES EARTH LOOK LIKE FROM SPACE?
(1,2)

MATERIALS:

Earth photos from the National Aeronautics and Space Administration (NASA)

PROCEDURE:

(1) Observe photographs of Earth taken by NASA.
(2) Based on your observations, what is the shape of Earth?

F-14. IN WHAT DIRECTION IS A SHADOW CAST BY A VERTICAL POLE AT LOCAL NOON?
(1,2)

MATERIALS:

flagpole or stick
compass

PROCEDURE:

At noon, determine the direction of the shadow cast by a flagpole or stick placed vertically into the ground.

RESULTS:

The shadow will point in a northerly direction.

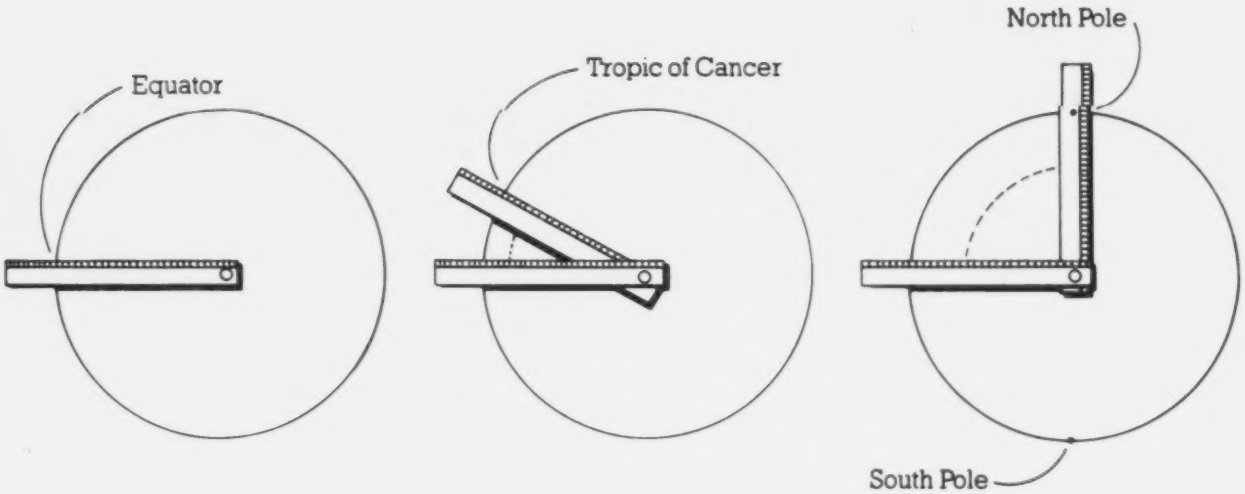
F-15. WHAT IS LATITUDE?
(18,20,17)

MATERIALS:

two rulers or flat sticks with a hole punched in one end of each
a small brass fastener
a styrofoam sphere (the size of a tennis ball or larger) cut in half vertically with the equator, the tropic of Cancer, the North and South Poles, and the location of New York State drawn on the outside of the hemisphere and the center of the hemisphere indicated on the flat side
marking pen
protractor

PROCEDURE:

(1) Fasten the two rulers by placing the brass fastener through their pre-punched holes.
(2) Place the hinge of the rulers at the center of the flat side of the hemisphere, with the rulers closed and lined up with the equator line (see diagram). Use the protractor to measure the resulting angle. Record this angle.
(3) Repeat (2), this time lining up one side of the hinged rulers with the equator and the other with the tropic of Cancer. Record the angle. Repeat for the North Pole, South Pole, and the location of New York State.
(4) The tropic of Capricorn is 23 1/2° below the equator. Use the protractor and hinged rulers to show where it should be placed. Check your answer with your teacher. Draw several other parallels of latitude on your hemisphere and label them.
(5) Explain how the locations of lines of latitude are determined.



RESULTS:

The latitudes of the lines and locations drawn on the hemisphere are as follows.

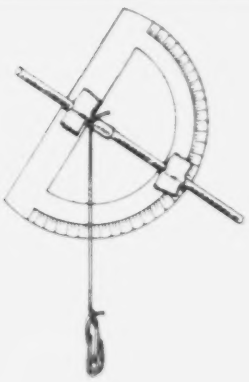
Equator	0°
Tropic of Cancer	23 1/2°N
New York State	42°N (approximate)
North Pole	90°N
South Pole	90°S

F-16. HOW IS A SIMPLE SEXTANT (ASTROLABE) CONSTRUCTED?

(4)

MATERIALS:

protractor
straw
tape
string (about 10-15 cm)
small weight
file card (13 x 20 cm)



PROCEDURE:

(1) Place the protractor on the file card and trace its outline. Place the proper degree markings on the inside of the outline. Cut out the protractor you have drawn.

(2) Attach the weight to one end of the string. Tape the other end of the string and the straw to the cardboard protractor as shown in the diagram.

F-17. HOW CAN THE LATITUDE OF A LOCATION BE FOUND?

(4)

MATERIALS:

sextant (astrolabe) constructed in **Activity F-16**

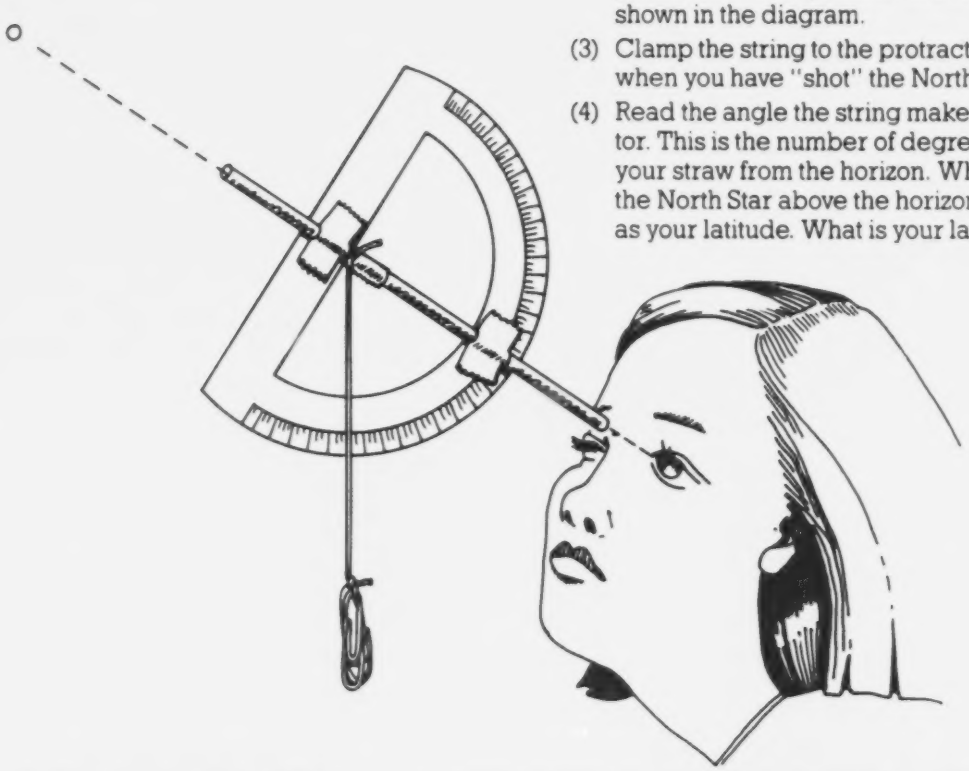
PROCEDURE:

(1) At home on a clear night, find the North Star (see **Activity F-3**).

(2) "Shoot" the horizon with your sextant. Is your straw parallel with the ground? Shoot the North Star as shown in the diagram.

(3) Clamp the string to the protractor with your finger when you have "shot" the North Star.

(4) Read the angle the string makes with the protractor. This is the number of degrees you have raised your straw from the horizon. What is the altitude of the North Star above the horizon? This is the same as your latitude. What is your latitude?



F-18. WHAT IS LONGITUDE?

(18,20,17)

MATERIALS:

same as in **Activity F-15**, but with the sphere cut horizontally, the continents of the Northern Hemisphere outlined, and the Prime Meridian and International Date Line drawn

PROCEDURE:

(1) Place the hinge of the rulers constructed in **Activity F-15** at the center of the flat side of the hemisphere, with the rulers closed and lined up with the Prime Meridian line (see diagram). Use the protractor to measure the resulting angle. Record this angle.

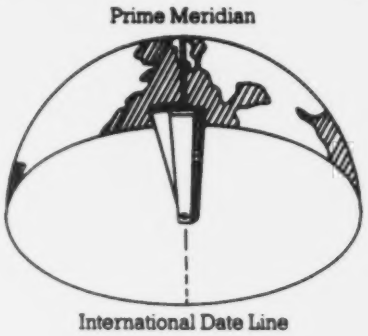
(2) Repeat (1), this time lining up one side of the hinged rulers with the Prime Meridian and the other with the International Date Line. Record the angle.

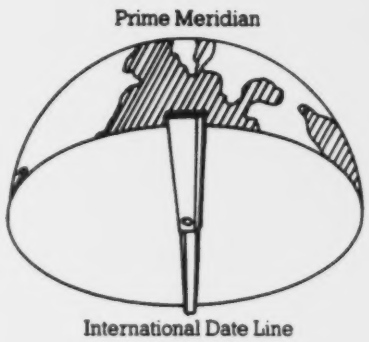
(3) Locate New York State on the outline of North America. Repeat (2) and record the angle.

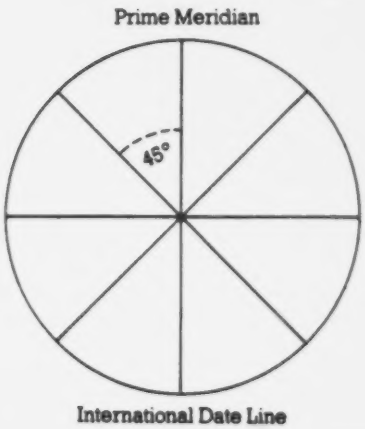
(4) Place the protractor on the flat side of the hemisphere, lined up with the Prime Meridian. Starting at the Prime Meridian, measure and mark 45° angles around the flat side as shown in the diagram. Locate where the North Pole would be on the outside of the hemisphere. Draw lines from each 45° mark to the pole. Label each with the correct longitude.

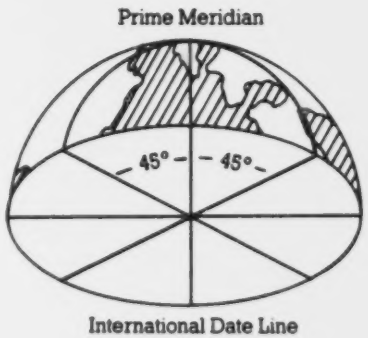
RESULTS:

The Prime Meridian passes through Greenwich, England and is 0 degrees longitude. New York State's longitude is approximately 75 degrees West. The International Date Line is 180 degrees. Longitude is measured in degrees east and west of the Prime Meridian.









F-19. HOW IS LONGITUDE DETERMINED?

(17)

MATERIALS:

a stick
two clocks, one set at Greenwich Mean Time (5 hours earlier than Eastern Standard Time)
compass

PROCEDURE:

(1) Draw a north-south line on the ground on a sunny day.
(2) Set a vertical stick at the south end of the line.
(3) When the shadow of the stick falls along the line, set the second clock at 12 o'clock (local) noon.
(4) Subtract and find the difference in time between the two clocks to the nearest hour.
(5) Fifteen degrees of longitude equals one hour in time. What is the longitude at your location?

RESULTS:

Since one hour of time equals 15° of longitude, the longitude of New York State is 5 hours x 15° or 75° New York State is west of the Prime Meridian (Greenwich, England) so its longitude is 75° West.

F-20. WHAT HAPPENS TO THE LENGTH OF A SHADOW DURING THE COURSE OF ONE DAY?

(1,2,14,17)

MATERIALS:

a stick 60 to 100 cm long
meterstick
graph paper
paper and pencil

PROCEDURE:

(1) On a sunny day, place a stick vertically into the ground.
(2) Starting as early in the morning as you can, measure the length of the shadow cast by the stick each hour. Record your data in a data table.
(3) Make a bar graph of the results.

RESULTS:

The length of the shadow cast by an object is long in the early part of the day, becomes shortest at local solar noon, and then gradually lengthens again. The Sun is directly over the observer's meridian when the shadow is shortest.

F-21. HOW CAN SUN TIME BE DETERMINED LOCALLY?

(4,1,14,17)

MATERIALS:

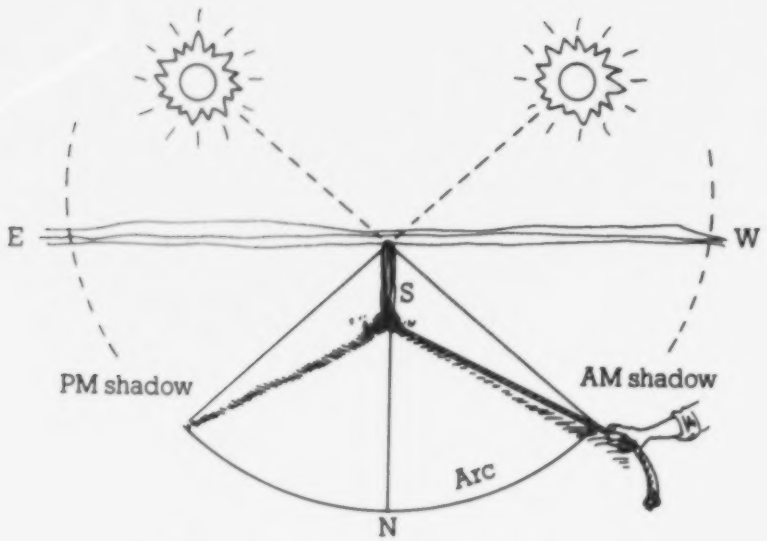
a stick 120 to 150 cm long
a stout piece of cord 6-10 m long
watch or clock

PROCEDURE:

(1) Select a level area of the school grounds and drive the stick into the ground vertically.
(2) As shown in the diagram, tie the end of the cord to the base of the stick. Two or three hours before noon, mark the length of the shadow with the cord.
(3) Using this length of cord as a radius, draw an arc on the ground.
(4) Mark the point where the shadow touches the arc.
(5) In the afternoon, watch for the tip of the shadow to just touch the arc. Again mark the point. (Other classmates may do this for you during their science class.)
(6) With the two points as centers, use the cord to bisect the arc. Now stretch the cord between the stick and the point of bisection. The cord lies on a north-south line, a bit of the local meridian.

(7) The following day set a watch or clock at 12 o'clock noon when the shadow of the stick is in line with the cord. This timepiece will be keeping Sun time.

(8) Compare your Sun time with the classroom clock. How do Sun and clock time compare?



F-22. HOW IS A SUNDIAL CONSTRUCTED?

(4,17)

MATERIALS:

a cylindrical cardboard container, 6 cm in diameter and 15 cm long, cut in half lengthwise
pieces of cardboard
string
stapler
scissors

PROCEDURE:

(1) As shown in Diagram A, mark the middle of the top and bottom of the cardboard container. Run a string between these points, being careful not to pull the ends of the container in when fastening the string.

(2) As shown in Diagram B, cut two side pieces and staple them to the container. The folds form the base of the sundial. The sides provide the necessary angle to keep the string parallel to Earth's axis.

(3) Place the sundial in a window so that the string is in a north-south direction and the base is level.

(4) Observe the shadow the string casts over time.

(5) Do research to find out how to calibrate your sundial.

Diagram A

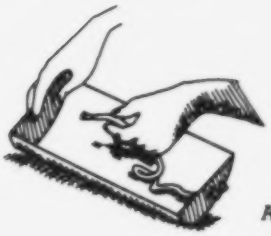
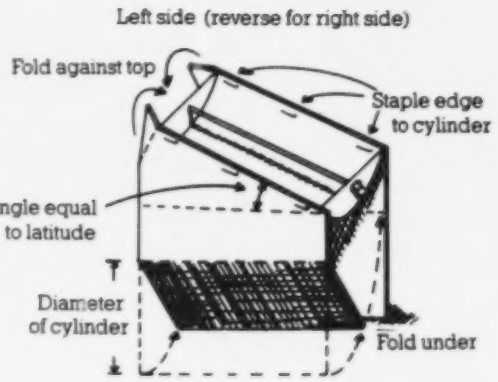
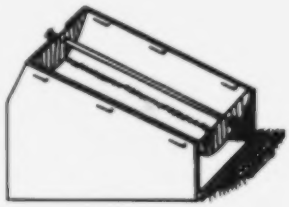


Diagram B





RESULTS:

The shadow produced by the Sun will move inside the cylinder at the rate of 15 degrees every hour. The shadow will move up and down with the time of year and can be calibrated for both time of day and time of year.

F-23. HOW DOES CLOCK TIME COMPARE WITH SUN TIME?

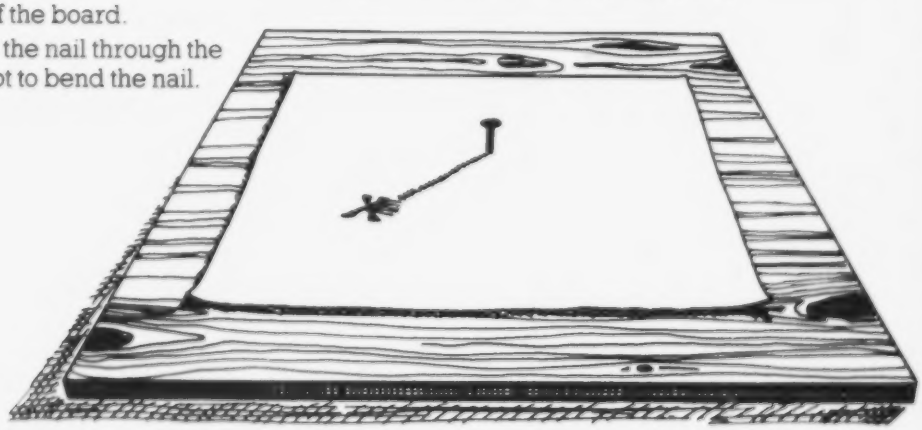
(1,14,17)

MATERIALS:

a long nail
hammer
square board
paper

PROCEDURE:

(1) Place the paper in the center of the board.
(2) As shown in the diagram, drive the nail through the paper and board. Be careful not to bend the nail.
(3) Place the board where it will receive sunlight all day.
(4) Periodically during the day, mark the tip of the shadow cast by the nail and the time it was cast.
(5) Repeat (4) for several days, making sure to mark the paper when the shadow is shortest. Organize and analyze your results.
(6) At what time of day was the shadow shortest each day? Is this the same time every day?



(7) Repeat this procedure once every 2 or 3 months, making sure to place the board in exactly the same direction each time. Analyze your results. How does the time at which the shadow is shortest change over the course of a year?

RESULTS:

Clock time (mean solar time) is based on the average length of a solar day from noon to noon. Noon by clock time is seldom the same as noon by Sun time.

F-24. WHY IS THE INTERNATIONAL DATE LINE NECESSARY?

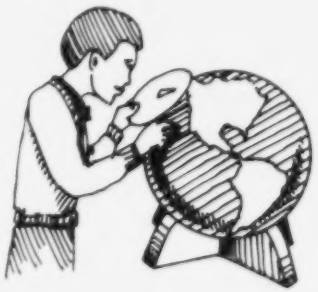
(8,20)

MATERIALS:

an index card 12.5 x 20 cm
globe
scissors
a brass paper fastener

PROCEDURE:

(1) Use the index card to make a clock with only an hour hand.
(2) Working with a partner, pretend you are making a super fast flight around Earth, taking just a few minutes for the entire trip. Select any starting point you wish.
(3) One of you should be the navigator, charting off the 15° intervals on the globe. The other should be in charge of the clock, changing the hours and calling out the hour and day as the navigator reads off the 15° intervals.
(4) What happened when you reached home a few minutes after you started?
(5) Ask your teacher to show you the International Date Line on the globe and to explain how to change the date according to the direction of travel.
(6) Repeat (2) and (3), making the proper date changes at the International Date Line.
(7) Take turns asking each other time questions. For example, if it is 9:00 a.m. in Greenwich, England, what time and day is it in New York State?



RESULTS:

When students complete (3), they will find themselves arriving home a day later according to their clock time, when actually it is only a few minutes later. When the International Date Line is explained, they can then adjust their clocks properly.

F-25. HOW DOES THE DAY VARY AROUND EARTH IN THE COURSE OF A 24-HOUR PERIOD?

(18,20)

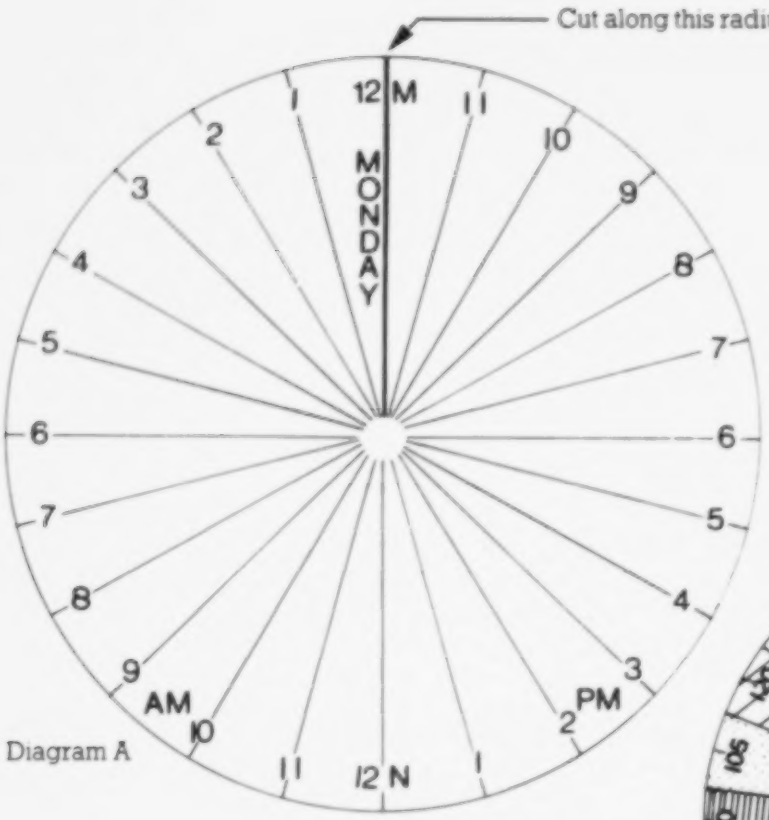


Diagram A

Diagram B

Copy these diagrams onto 12.5 × 20 cm index cards

MATERIALS:

disks provided on index cards
scissors

ADVANCE PREPARATION:

Duplicate the diagrams of the disks on index cards.

PROCEDURE:

(1) Cut out the two disks provided.
(2) Cut along the radius of each disk as indicated.
(3) Place the smaller disk on top of the larger disk.
(4) Align the 12 N position on the larger disk with the Prime Meridian line on the smaller disk (see Diagram C). Right now what date is it over the entire Earth?
(5) Rotate the top disk counterclockwise, sliding its leading edge under the edge of the larger disk. Stop when the International Date Line aligns with 1 A M (see Diagram D). What time and date is it at the Prime Meridian? In the Eastern Time Zone?
(6) What happens to the times and date at these two locations as you continue to rotate the disk (see Diagram E)?
(7) When it becomes Monday at the Prime Meridian, what date and time is it at the International Date Line?

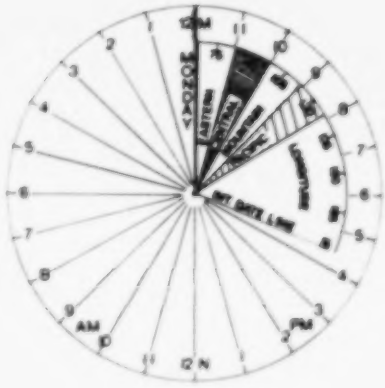
RESULTS:

While some time zones on Earth are experiencing one day, other time zones experience the next day. The time zones experiencing a particular day change as Earth rotates.

Diagram C

Diagram D

Diagram E



F-26. HOW CAN A SKY CHART BE USED TO IDENTIFY THE CONSTELLATIONS?

(18,1,2)

MATERIALS:

simple sky charts for student use (a winter sky chart is provided)

PROCEDURE:

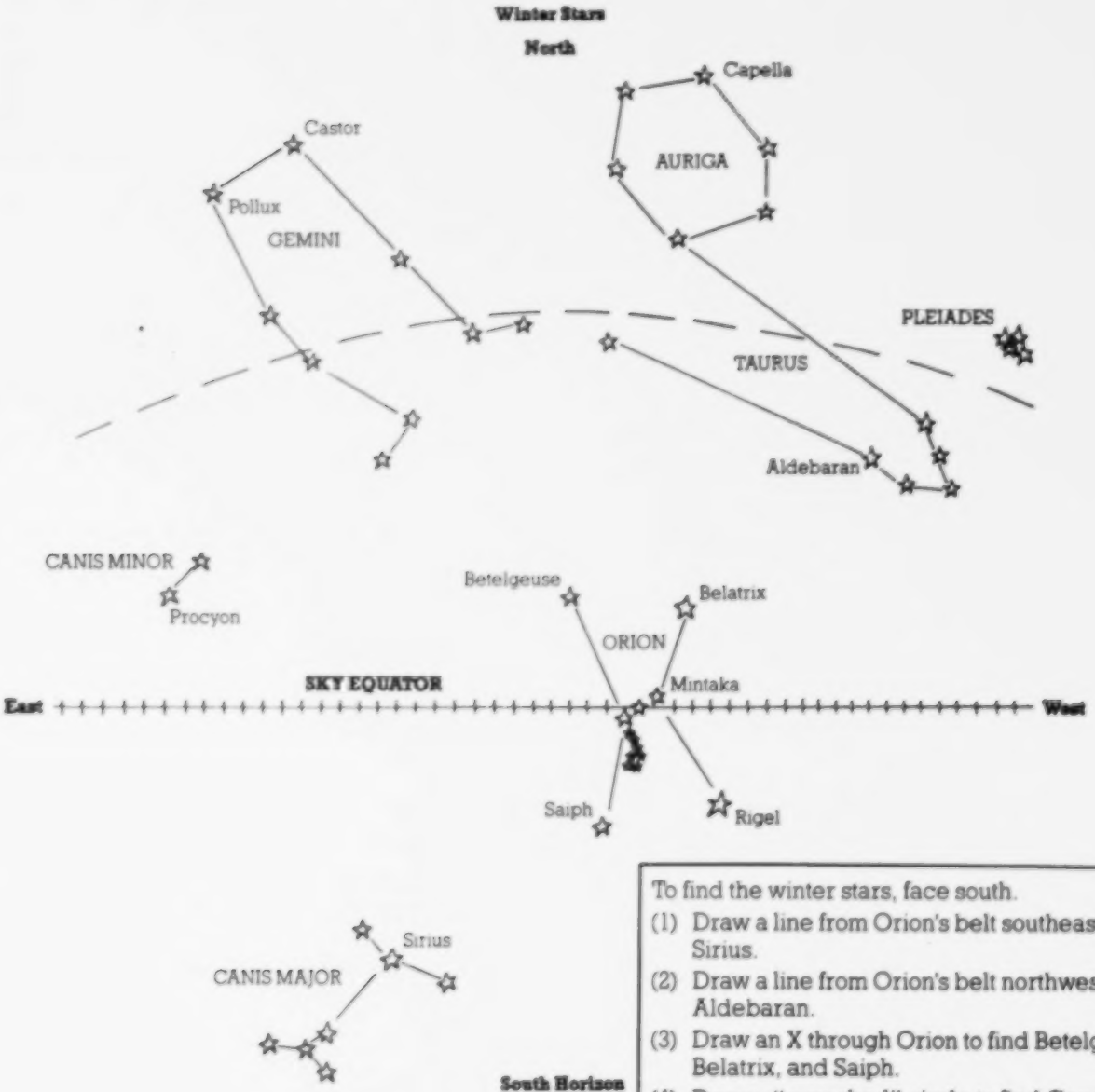
(1) Point out the features of the sky chart to students, noting how to hold the sky chart, how to orient it in the proper direction, and other pertinent information.

(2) Have students practice the proper use of the sky chart in class.

(3) Assign students to use the sky chart on the next clear night. They should note the constellations that they are able to identify. Students might want to involve their parents in this activity.

RESULTS:

The constellations that students will be able to identify will vary with the season and with the student. The most readily identifiable constellations include the Big and Little Dippers (visible all year) and Orion (visible in winter). Students should find that sky charts are easy and fun to use, and they may develop a life-long hobby of star gazing.



To find the winter stars, face south.

(1) Draw a line from Orion's belt southeast to find Sirius.

(2) Draw a line from Orion's belt northwest to find Aldebaran.

(3) Draw an X through Orion to find Betelgeuse, Rigel, Belatrix, and Saiph.

(4) Draw a "squashed" circle to find Capella, Castor, Pollux, Procyon, Sirius, Rigel, and the Pleiades.

F-27. HOW IS A REFRACTING TELESCOPE CONSTRUCTED?

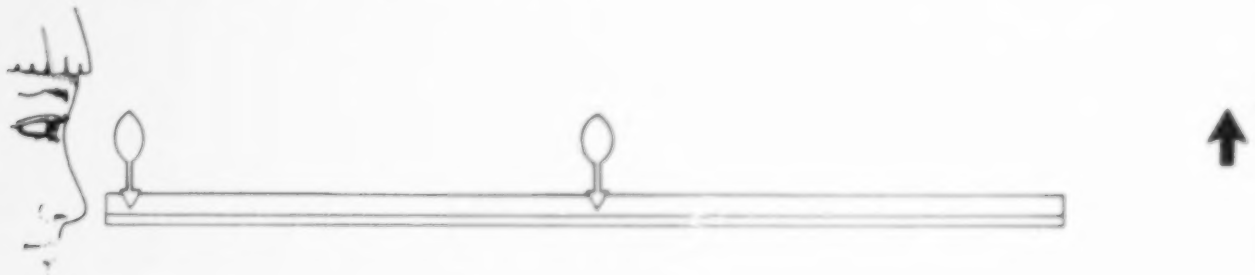
(1,2,14,17)

MATERIALS:

two convex lenses
two lens brackets
meterstick

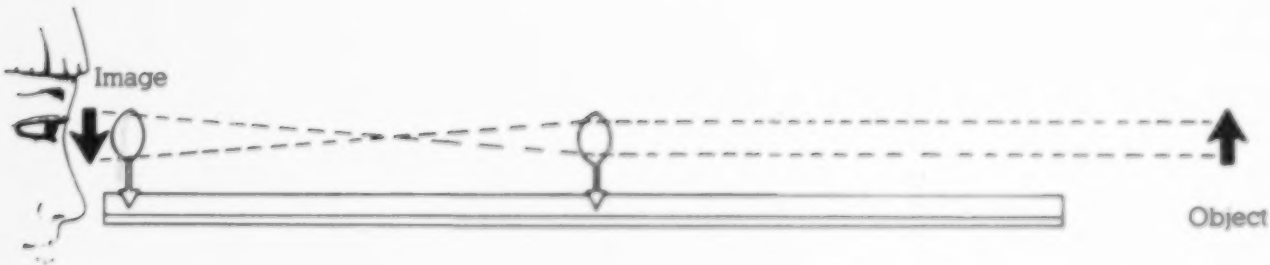
PROCEDURE:

(1) As shown in the diagram, place a convex lens in each of the lens holders and mount each lens holder on a meterstick.
(2) Look through both lenses. You may have to vary the positions of the lenses to focus properly the image you are viewing. What do you see?
(3) Answer the following questions:
   (a) How does the size of the object being viewed through your refracting telescope appear to be affected?
   (b) How does the orientation (up-side down or right-side up) of the object you are viewing through your refracting telescope appear to be affected?
(4) Draw a diagram showing how the light from the object reaches the observer's eye.



RESULTS:

Light rays from the object cross as they pass through the convex lenses. The image will appear larger and inverted.



F-28. HOW IS A REFLECTING TELESCOPE CONSTRUCTED?

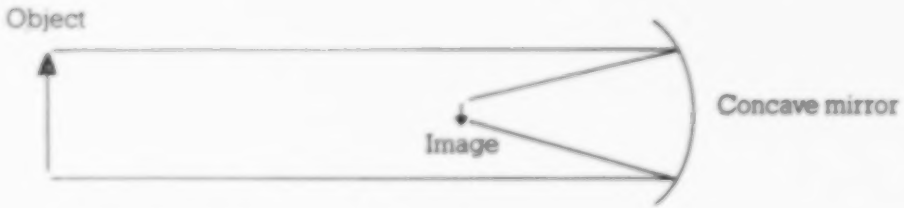
(1,2,14,17)

MATERIALS:

concave mirror
plane mirror

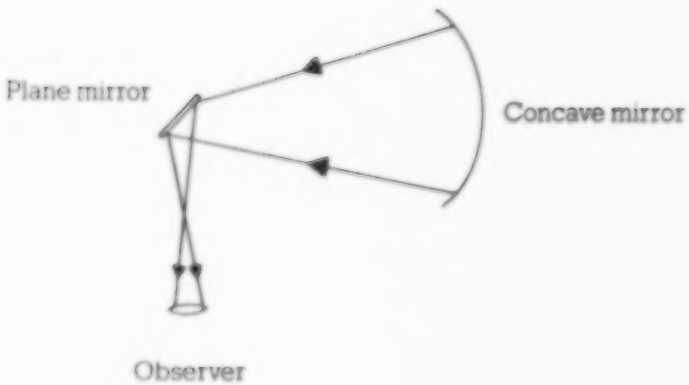
PROCEDURE:

(1) View an object using the concave mirror.
(2) Draw a diagram tracing the light rays from the object to the image of the object.
(3) Place the plane mirror in the focal plane of the object viewed with the concave mirror.
(4) Draw a diagram tracing the light rays from the object to the concave mirror to the plane mirror to the observer's eyes.
(5) Based on this investigation, answer the following questions:
   (a) How does a concave mirror form an image?
   (b) Why is a plane mirror a necessary component of a relecting telescope?



RESULTS:

A reflecting telescope is composed of a concave mirror to gather and focus the light from an object, and a plane mirror to bring the image to one side.



F-29. WHAT WOULD A SIMPLE SCALE MODEL OF THE MOON-EARTH SYSTEM LOOK LIKE?

(18,20)

MATERIALS:

paper
ruler
scissors
string
tape

PROCEDURE:

(1) Earth's diameter is approximately 12,800 km. The Moon's diameter is approximately 3,500 km. The distance between Earth and the Moon is about 386,000 km.
(2) Devise a scale to make a scale model of the Moon and Earth.
(3) Cut a string whose length would represent the distance between the Moon and Earth.
(4) Construct scale models of the Moon and Earth from paper. Tape your models to opposite ends of the string to complete your scale model.

F-30. HOW ARE THE MOON'S PERIODS OF ROTATION AND REVOLUTION RELATED?

(18, 20)

MATERIALS:

globe

PROCEDURE:

(1) Set the globe in a position where a student can move around it.
(2) Ask a student to volunteer to represent the Moon and to revolve around the globe in such a way that the student always is facing Earth.
(3) Help the class to analyze what the student is doing in terms of the periods of revolution and rotation of the Moon. Use the four classroom walls as frames of reference.

RESULTS:

The Moon's period of revolution is equal to its period of rotation.

F-31. WHAT PHYSICAL FEATURES OF THE MOON CAN WE SEE?

(1, 2)

MATERIALS:

field glasses (6 or 7 power) or a telescope (optional)
a map of the Moon with physical features labeled
a map of the Moon with physical features indicated but not labeled

PROCEDURE:

(1) Provide students with both a labeled and unlabeled map of the Moon and a list of some of the more obvious physical features.
(2) Ask students to use their unaided eyes, or field glasses or a telescope if either is available, to identify as many features of the Moon as they can actually observe. These features should be labeled on their unlabeled lunar maps.

RESULTS:

Some physical features of the Moon are identifiable with the unaided eye. Others require field glasses or a telescope. The view through a telescope will appear upside down.

F-32. WHY DO WE SEE "PHASES" OF THE MOON?

(18, 20)

MATERIALS:

projector
kickball or basketball

PROCEDURE:

(1) Have the class sit clustered together at one end of the room. They will represent Earth.
(2) Place the projector at the opposite end of the room to represent the Sun.
(3) Revolve the ball, which represents the Moon, around the students.
(4) Ask students to draw pictures of the portions of the lighted side of the ball that they can see as it revolves around them. What portion of the ball actually is always lighted?
(5) Ask students to identify the phases of the Moon from a text or reference sheet.

RESULTS:

As the Moon revolves around Earth, we on Earth are not always in a position with respect to the Sun and Moon to be able to see the full lighted half of the Moon.

F-33. HOW DO LUNAR AND SOLAR ECLIPSES OCCUR?

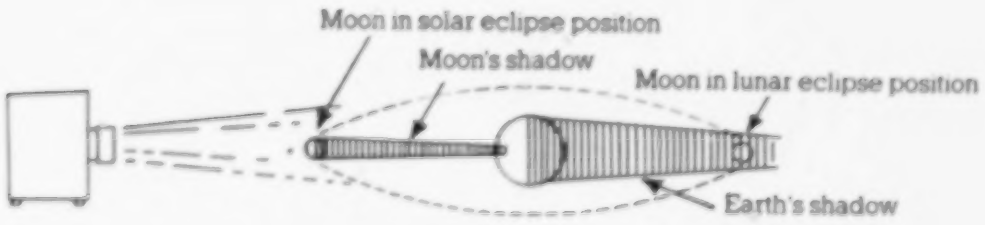
(18, 20)

MATERIALS:

a projector to represent the Sun
a globe to represent Earth
a tennis ball to represent the Moon

PROCEDURE:

(1) Set up the projector and globe so that you can move the tennis ball into and out of Earth's shadow.
(2) Ask students to describe the shape of Earth's shadow on the Moon.



(3) Repeat the demonstration to show the difference between a partial and total lunar eclipse.
(4) Repeat again to show why a lunar eclipse doesn't occur at every full Moon.
(5) Now move the tennis ball between the projector and globe to demonstrate a solar eclipse. Ask students why few observers ever see a solar eclipse.

RESULTS:

Eclipses of the Moon and Sun occur as the result of the relative position of the Sun, Earth, and Moon as the Moon and Earth revolve. Lunar eclipses are more commonly observed than solar eclipses because everyone on the night side of Earth can see them (assuming no cloud interference). During solar eclipses, only those observers within the dark shadow (umbra), usually about 100 km or less wide, can see the total eclipse.

F-34. HOW CAN SUNSPOTS BE SEEN?

(1, 2, 14)

MATERIALS:

binoculars
masking tape
a sheet of white unlined paper

PROCEDURE:

(1) Go outdoors on a sunny day. Use the tape to cover the lens on one side of the binoculars.
(2) Place the paper on the ground.
(3) Place the binoculars about 20 cm above the paper, with the eyepiece facing the paper.

Caution: Never look directly at the Sun. The Sun's radiation can damage your eyes.

(4) Move the binoculars back and forth slowly until you have focused an image of the Sun on the paper.
(5) Can you find any sunspots on the image of the Sun's surface? If so, sketch the image of the Sun and indicate the sunspots.
(6) Repeat this activity for several days. Do the sunspots appear to move?

RESULTS:

Sunspots appear as small, dark, irregular spots on the surface of the Sun. Sunspots appear to move across the face of the Sun.

F-35. DO SUNSPOTS CHANGE IN NUMBER FROM YEAR TO YEAR?

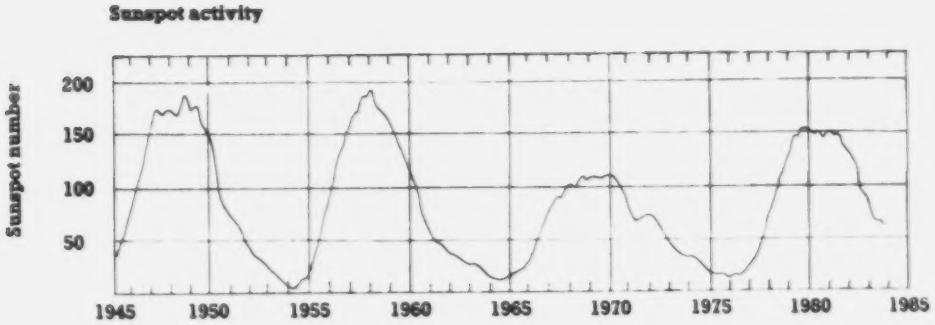
(14,17)

MATERIALS:

graph of sunspot activity provided
reference materials

PROCEDURE:

(1) Study the graph of sunspot activity over time.
(2) From the graph, answer the following questions:
    (a) What are the years of sunspot maxima?
    (b) What are the years of sunspot minima?
    (c) Calculate the average number of years between maximas.
    (d) Calculate the average number of years between minimas.
    (e) Predict the number of sunspots that will occur on the year you graduate from high school.
(3) What effect do sunspots have on Earth and human activities?



* Reprinted courtesy of *Sky and Telescope*, p. 476, November, 1984

RESULTS:

The number of sunspots is always changing and reaches a maxima (peak number) about every 11 years.

F-36. ARE ALL STARS ALIKE?

(18, 20)

MATERIALS:

Hertzsprung-Russell diagram provided

PROCEDURE:

(1) Study the Hertzsprung-Russell (H-R) diagram provided. An H-R diagram classifies stars by

Star	Color	Brightness	Size	Temperature	Life Span
Spica					shortest
Regulus					short
Sirius					fairly short
Star with Sirius (dying star)					shorter than average
Procyon					average
Rigel					longer
Betel-geuse (dying star)					longest

brightness and temperature. The diagram provided classifies only a few stars. The x axis indicates the relative color and temperature of a given star, while the y axis indicates its relative brightness. Relative sizes of the stars are shown by the size of the "point" drawn on the diagram.

(2) Use the H-R diagram to complete the data table provided.

(3) Answer the following questions:

(a) How is the temperature of a star related to its color?

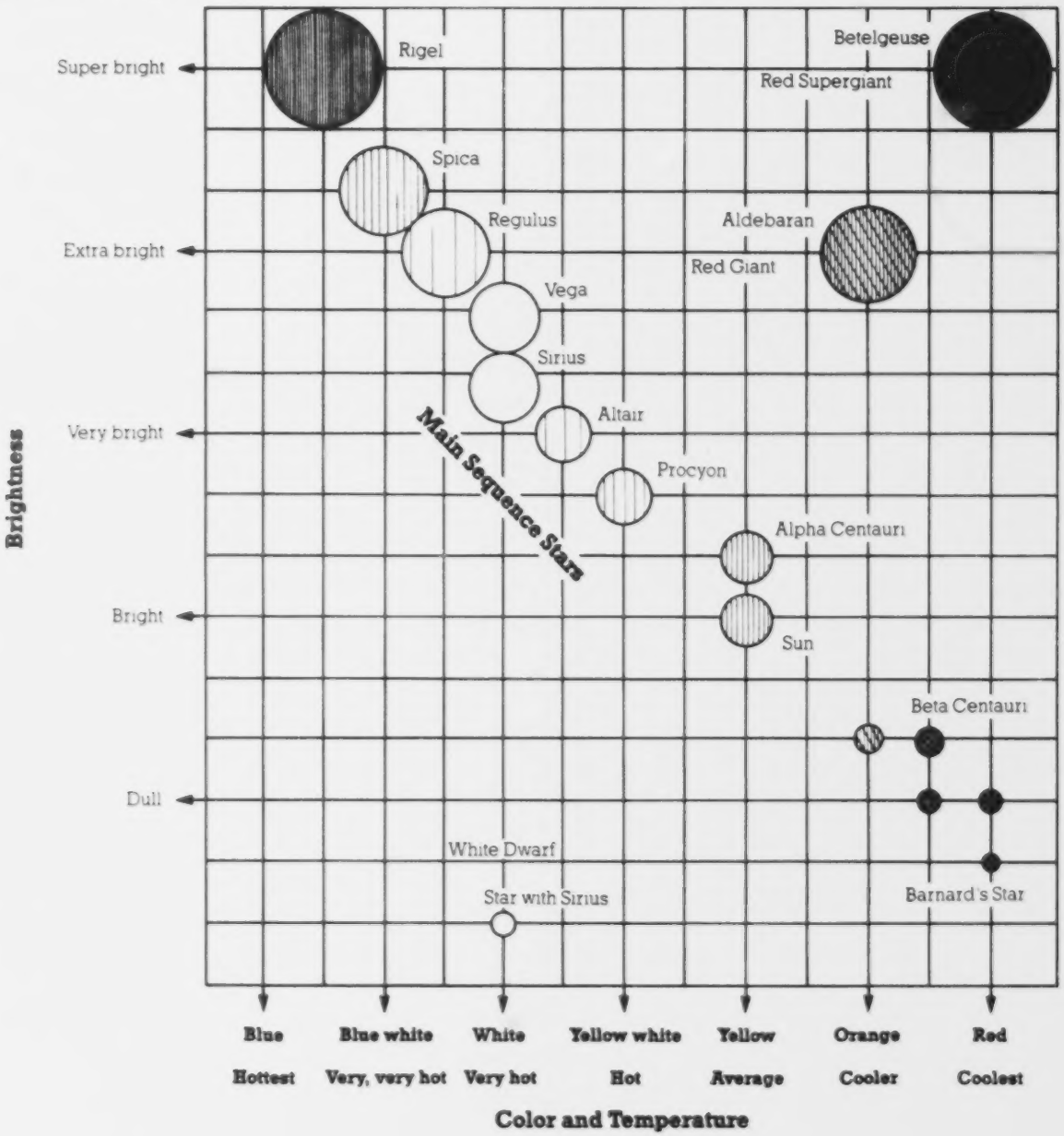
(b) How are the temperature and color of the main sequence stars on the diagram related to their size? What are the exceptions?

(c) How are the temperature, size, and color of stars related to their life span? Again, what are the exceptions?

RESULTS:

Stars may be classified to show the relationship between color, surface temperature, size, and brightness.

Hertzsprung — Russell Diagram



F-37. HOW CAN WE MAKE A MODEL OF THE SHAPE AND MOTION OF THE MILKY WAY GALAXY?

(18, 19, 20)

MATERIALS:

a cup of hot chocolate
powdered cream
spoon
reference materials on galaxies

PROCEDURE:

(1) Sprinkle some powdered cream onto the surface of the hot chocolate.
(2) Gently turn the cup a few times so that the liquid begins to rotate in the cup.
(3) Observe the motion of the powdered cream. Describe the motion of the cream and the shape that it takes.
(4) Does your model have spiral arms? If so, do the arms rotate faster or slower than the center?
(5) In what other ways is your model like a galaxy?
(6) What type of galaxy is your model most like?
(7) If this were a model of the Milky Way galaxy, where would the Sun be located?

F-38. WHAT ARE THE RELATIVE DISTANCES OF THE PLANETS FROM THE SUN?

(18, 20)

MATERIALS:

adding machine tape or string, approximately 6.5 m
meterstick
marking pen

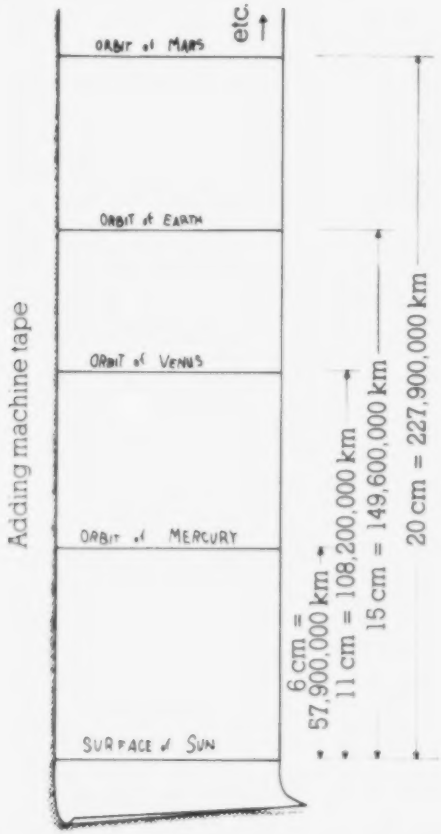
PROCEDURE:

(1) Study the actual and scale distances of the planets from the Sun, as given in the data table.
(2) About 2 cm in from the end of the tape or string, mark and label a line that represents the surface of the Sun. (If using string, a knot can be the marker, with a label tied to it.)
(3) Measure, mark, and label the distances of all the planets from the Sun. Display your scale model.
(4) Answer the following questions:
   (a) How do the distances of the inner planets from the Sun compare to those of the outer planets?
   (b) Which planets are closest to Earth?

DATA TABLE

Planet	Distance From Sun (km)	Scale Distance (1 m = 1 billion km)
Mercury	57,900,000	6 cm
Venus	108,200,000	11 cm
Earth	149,600,000	15 cm
Mars	227,900,000	20 cm
Jupiter	778,300,000	80 cm
Saturn	1,427,000,000	1.4 m
Uranus	2,869,600,000	2.9 m
Neptune	4,496,600,000	4.5 m
Pluto	5,900,000,000	5.9 m

(c) Based on this activity, what do you think most of the solar system is composed of?



RESULTS:

The planets vary in their distances from the Sun, with the inner planets closest and the outer planets very much farther away. Most of the solar system is composed of empty space.

F-39. HOW DO THE SIZES OF THE PLANETS COMPARE TO ONE ANOTHER?

(18, 20)

MATERIALS:

construction or standard paper
scissors
metric ruler or meterstick
marking pen or pencil

PROCEDURE:

(1) Choose one of the scales given in the data table provided. Use the scale to draw the scale diameters of the planets. To draw a circle, you may want to draw several diameters which cross at the midpoint (see diagram), and then connect them with a smooth circular line. Label each circle with the name of the planet it represents. If you have chosen either the first or third scale, cut out the circles and display them.

(2) Answer the following questions:
   (a) How do the sizes of the planets compare to one another?
   (b) How do the sizes of the inner planets compare to the sizes of the outer planets?
   (c) What are the largest two planets?
   (d) Which planet is closest in size to Earth?
   (e) What common item would be comparable to the scale size of each planet (for example, a golf ball, tennis ball, beach ball, ping-pong ball, orange, grapefruit, walnut, and so on)?

DATA TABLE

Planet	Equatorial Diameter (km)	Diameters Converted to Fill a Standard Page*	Diameters Converted to Fill a Chalkboard**	Diameters Converted to 1 cm = 1000 km
Mercury	4,880	0.7 mm	0.4 cm	4.9 cm
Venus	12,104	1.8 mm	0.9 cm	12.1 cm
Earth	12,756	1.9 mm	0.9 cm	12.8 cm
Mars	6,787	1.0 mm	0.5 cm	6.8 cm
Jupiter	142,800	2.1 cm	10.3 cm	1.4 m
Saturn	120,000	1.8 cm	8.6 cm	1.2 m
Uranus	51,800	8.0 mm	3.7 cm	52.0 cm
Neptune	49,500	7.0 mm	3.6 cm	50.0 cm
Pluto	2,500	0.4 mm	0.2 cm	2.5 cm
Sun	1,392,000	20.9 cm	100.0 cm	13.9 m

*These numbers were derived by multiplying the diameter in kilometers by 1.5×10^{-5}.
**These numbers were derived by multiplying the diameter in kilometers by 7.1839×10^{-5}.

RESULTS:

The planets vary in size a great deal. With the exception of Pluto, the outer planets are much larger in size than the inner planets. The distances from the Sun to the planets in **Activity F-38** are not drawn to the same scale as the diameters in this activity. Therefore, the scale distances between the planets and the circles representing their sizes cannot be put together into one scale model. The table below gives these measurements in the same scale.

DATA TABLE

Planet	Scale Diameter	Scale Distance
Mercury	2 mm	23 m
Venus	5 mm	43 m
Earth	5 mm	60 m
Mars	3 mm	91 m
Jupiter	5.7 cm	311 m
Saturn	4.8 cm	570 m
Uranus	2 cm	1.1 km
Neptune	2 cm	1.8 km
Pluto	1 mm	2.4 km

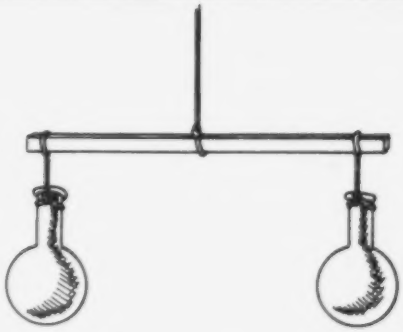
Scale: km $\times 1.0 \times 10^{-3}$ = mm

F-40. WHICH IS LIGHTER, WARM AIR OR COLD AIR?

(8, 9, 1, 14)

MATERIALS:

meterstick
two flasks
twine
scissors
candle



PROCEDURE:

(1) As shown in the diagram, suspend the meterstick from a support stand or the ceiling.
(2) Suspend a flask from either end of the meterstick. Adjust the flasks until they are balanced.
(3) Which do you think is lighter, warm air or cold air? Why?
(4) How could you use this setup to determine which is lighter? Write out your plan, making sure to state your hypothesis. Check your plan with your teacher, then try it out. What happens? Can you explain how this happens?
(5) How could you again balance the flasks? Try out your idea to see if it works.

RESULTS:

The air in the flask above the candle will be heated and will expand. Some of this air will be pushed out of the flask. The heated flask will then weigh less than the unheated flask, and will rise.

F-41. HOW IS LIFT PRODUCED?

(1, 14, 17)

MATERIALS:

two sheets of paper
a book
a straw
one small and one larger index card

PROCEDURE:

(1) Carry out each activity as shown in Diagrams A, B, and C.
(2) What happens in each activity? Explain what happens based on your knowledge of what causes lift.

Diagram A

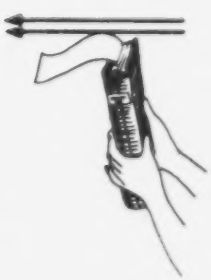


Diagram B

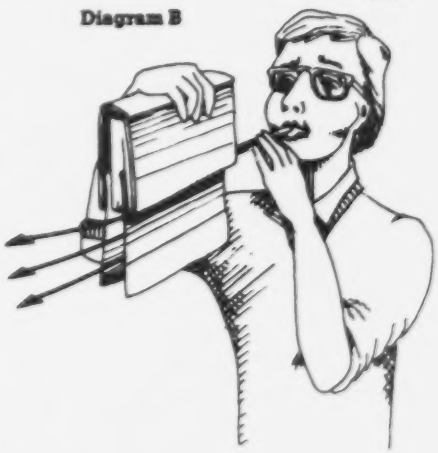
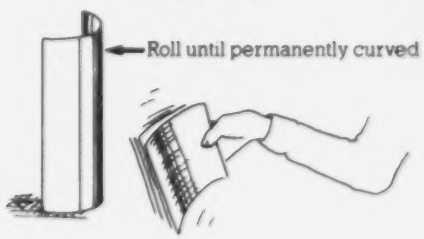


Diagram C



RESULTS:

In the activity depicted in Diagram A, the sheet of paper will rise. In B, the two papers will move together. In C, the index card will fall toward the fan. Moving air exerts less pressure than still air. In each case, the greater pressure of the still air causes the paper to move towards the moving air.

F-42. CAN THE LIFT OF AN AIRPLANE'S WINGS OVERCOME ITS WEIGHT?

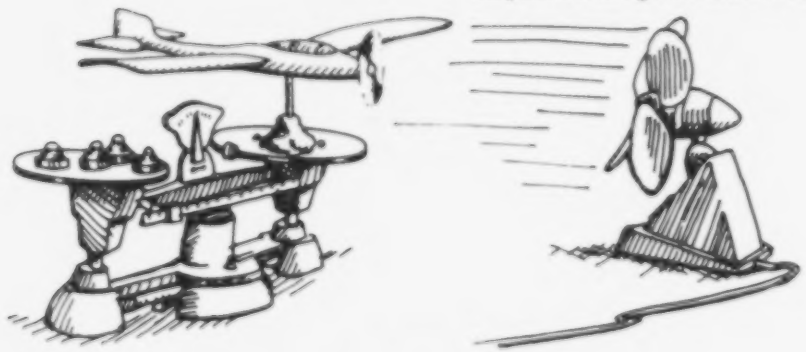
(Teacher Demonstration) (1, 14, 17)

MATERIALS:

a small model airplane
clay
a wooden dowel 7.5-12 cm in length
a pan balance and gram masses
a small electric fan
masking tape
rubber cement

PROCEDURE:

(1) As shown in the diagram, use the clay and the wooden dowel to secure the model airplane to one pan of the pan balance.
(2) Place gram masses on the other pan of the balance to balance it.
(3) Direct the air from the fan toward the airplane. What happens? Explain what happens.
(4) Place different materials on the wings of the airplane, such as masking tape or rubber cement. Repeat (3). What happens? What effect do different materials have on the lift of the plane's wings? If the lift is decreased by a material, explain why. What real conditions might cause the lift of an airplane's wings to be reduced?



RESULTS:

When air from the fan is directed toward the airplane, the pan balance becomes unbalanced, with the gram masses moving downward. This occurs because the airplane rises. The air moves faster over the top (which is curved) of the airplane's wings than the bottom (which is uncurved).

F-43. HOW DOES AN AIRPLANE PROPELLER PROVIDE THRUST?

(Teacher Demonstration) (1, 14, 17)

MATERIALS:

a small electric fan, with more than one speed if possible

a drawer from a desk, or a small flat board, large enough to hold the fan

several round pencils (or dowels)

Caution: Make sure students do not get too close to the fan or do not inadvertently reach for it. Make sure that the drawer will stop naturally before it reaches the end of the table top.

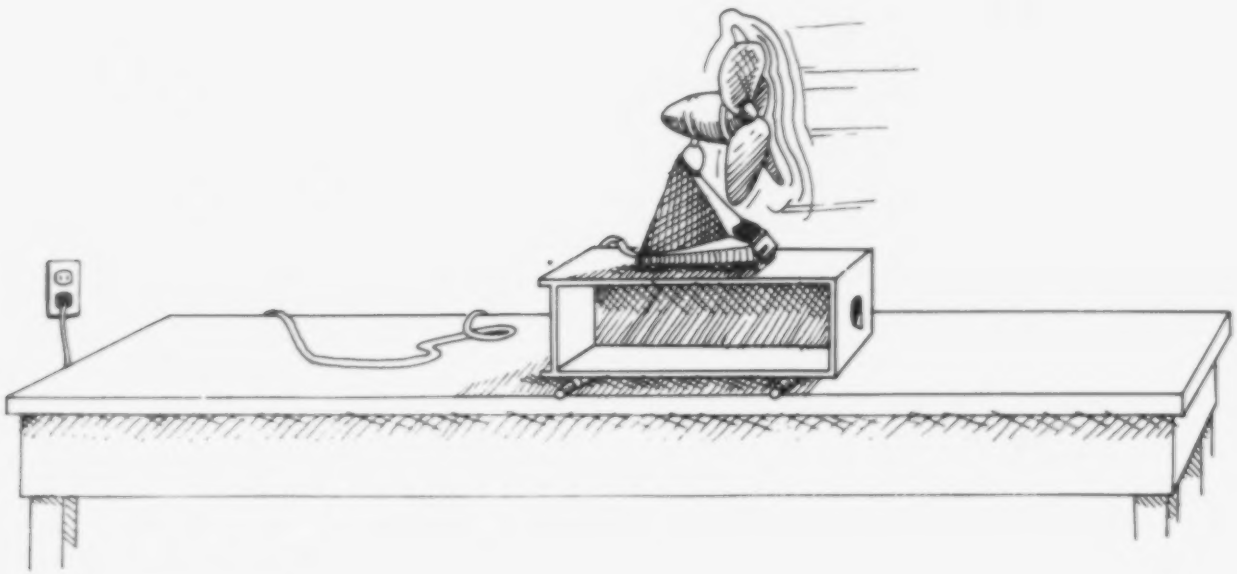
PROCEDURE:

(1) As shown in the diagram, set the drawer or board sideways on the pencils.

(2) Set the fan on the drawer.

(3) Turn on the fan. What happens? Explain what happens.

(4) What would happen if you increased the speed of the fan? State your hypothesis, then test it. What happened? Explain your results.



RESULTS:

As the blades of the fan push against the air in front of the fan (pushing the air forward from the fan), the fan itself is pushed backward, according to Newton's law of action and reaction. In a propeller, the blades push against the air behind the propeller, and the propeller and plane are pushed forward. The force that pushes the airplane forward is known as thrust.

F-44. HOW DO JET OR ROCKET ENGINES WORK?

(1, 14, 17)

MATERIALS:

PART A

a small bottle with a cork
two round pencils
one teaspoon of baking soda
a small piece of paper
one tablespoon of vinegar
safety glasses

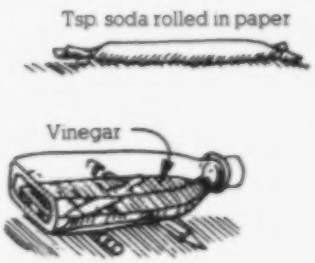


Diagram A

PART B

a nail and a hammer
a small can
heavy string or wire
water to fill the can
a sink or container to catch the water

PROCEDURE:

PART A

Caution: Wear safety glasses.

(1) Lay the bottle on the pencils as shown in Diagram A.
(2) Wrap the teaspoonful of baking soda in the paper and place it in the bottle.
(3) Place the tablespoonful of vinegar in the bottle and cork the bottle loosely.

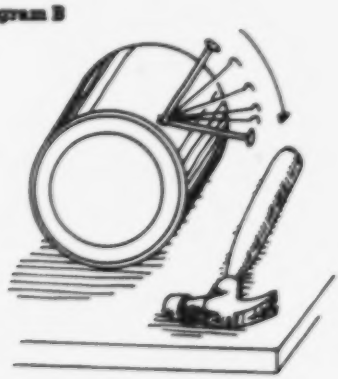
Caution: Do NOT observe the bottle from the corked end. Make sure the corked end is not pointed at anyone.

(4) What happens? Explain what happens.

PART B

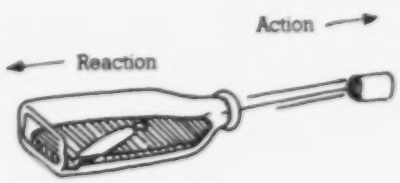
(1) Punch several nail holes around the bottom of the can as shown in Diagram B. Push the nail sideways in the same direction before removing it from each hole.
(2) Make three evenly-spaced holes near the top of the can. Use the wire or heavy string to suspend the can from these holes.
(3) Hold or suspend the can over the sink or container.
(4) Fill the can with water. What happens? Explain what happens.

Diagram B



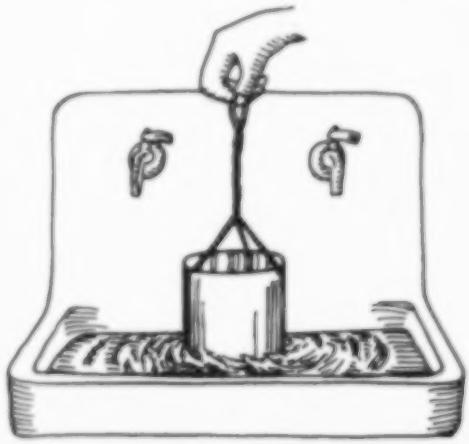
RESULTS:

In Part A, the chemical reaction between the baking soda and vinegar causes gas to accumulate inside the bottle. Increased pressure causes the cork on the bottle to pop and the gas is exhausted (the action force). The reaction force of the gas on the inside of the bottle causes the bottle to move in a direction opposite to the direction of the exhausting gas.



In Part B, the action force is the water escaping from the holes. The reaction force of the water inside the can results in the motion of the can. The can turns because of the angle at which the water escapes.

Jet aircraft and rockets move forward as the result of the principle illustrated here. The thrust is provided by the reaction force inside the engine, not by the action force of the exhausting gases.



F-45. WHAT IS A ROTOR?

(8, 9, 10, 12, 14)

PART A

MATERIALS:

scissors
paper clip
a diagram of a rotor on an index card

ADVANCE PREPARATION:

Duplicate the rotor diagram provided on a 7.5 x 12.5 cm index card.

PROCEDURE:

(1) Cut out the rotor provided by your teacher.

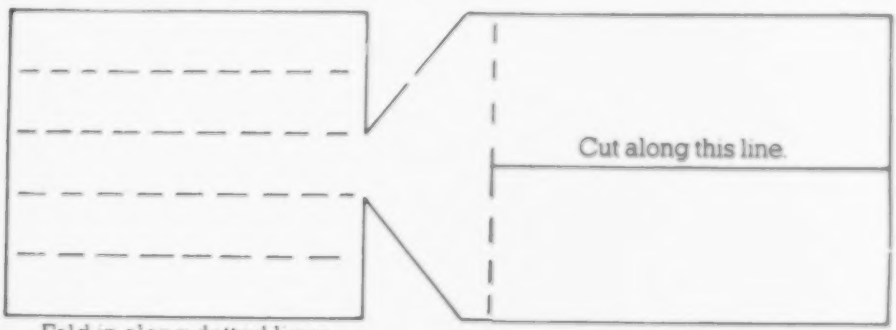
(2) Fold over the bottom section as shown in the diagram and fasten with a paper clip.

(3) Throw your rotor into the air. What happens?

(4) How could you make the rotor provide thrust? (That is, how could you make the rotor fall more slowly?) State your hypothesis and plan your investigation, then carry it out. How does a rotor work? How can you make a rotor provide more thrust?

RESULTS:

The rotor will not provide thrust until blades are cut and bent in opposite directions. The blades cause the rotor to spin, thus providing thrust. This thrust is not enough to overcome the force of gravity, but does reduce the rate of fall of the rotor.



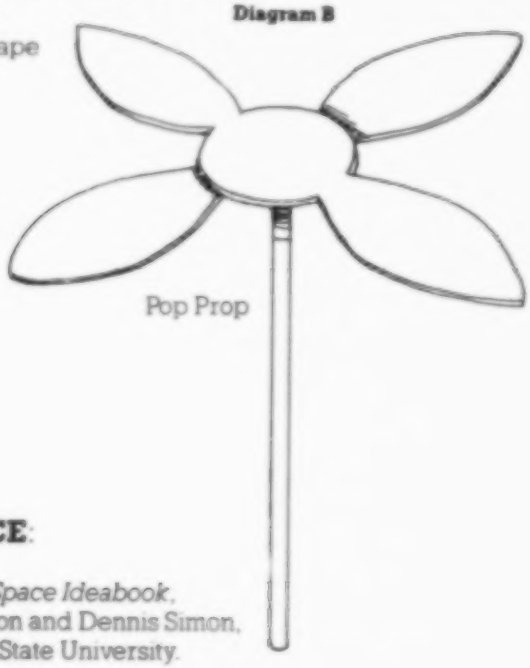
Fold in along dotted lines.

PART B

MATERIALS:

a push-up ice cream popsicle holder
a 12.5 x 17.5 cm index card
scissors
glue or tape

Diagram B



SOURCE:

Air and Space Ideabook,
Ted Colton and Dennis Simon,
Georgia State University.

PROCEDURE:

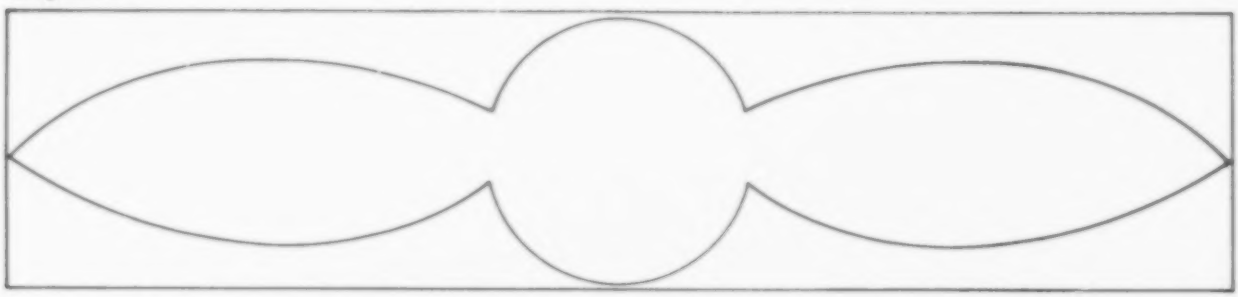
(1) Trace and cut out the prop pattern provided. Repeat to make a second prop.
(2) Glue or tape the props on the push-up holder (see Diagram B).
(3) Twist or curve the prop blades in the same direction. You now have a rotor.
(4) How could you make the rotor provide thrust? Hold the rotor handle between your left palm and right fingertips (see Diagram C). Hold your fingers straight and rigid.
(5) Tip the rotor away from yourself. Squeeze the handle firmly so that it doesn't slip.

Caution: *Always point the rotor away from yourself and others.*

(6) Roll your right hand forward smoothly all the way along the surface of your left hand. Be sure to launch smoothly, to maintain pressure between your hands, and to follow through.
(7) What happens?
(8) Can you catch your rotor? Can you make it fly in a curve? Can you make it return to you? What other tricks can you make it do?
(9) Can you make the rotor provide more lift? Try out your ideas.

Diagram C

Diagram A



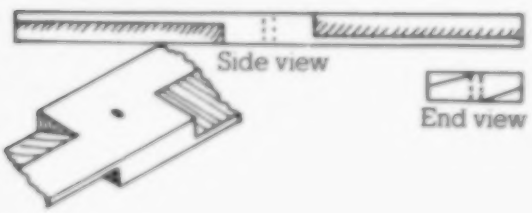
F-46. HOW DOES THE ROTOR PROVIDE LIFT AND THRUST FOR A HELICOPTER?

(1, 14, 17)

PART A

MATERIALS:

demonstration rotor



ADVANCE PREPARATION:

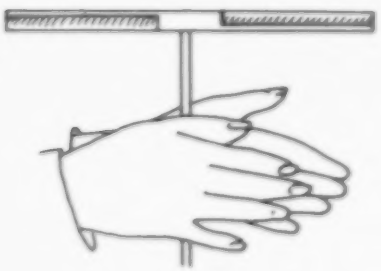
To construct the demonstration rotor, assemble the following materials:

a strip of soft wood 15 cm long, 2.5 cm wide, and 6 mm thick, with a small hole bored in the center

a dowel sized to fit in the hole described above

knife

Construct the rotor as shown in the diagram. Be sure to shave the blades as shown.



PROCEDURE:

(1) Pass the rotor around the room and allow students to spin the dowel between the palms of their hands.

(2) Ask students to describe in writing what happens. Discuss explanations.

RESULTS:

The rotating blades push the air downward and the reaction or thrust forces the rotor upward. The blades are also shaped to provide lift. Most helicopters have a motor-driven rotor, but some have jet engines mounted at the ends of the blades. The jet engines cause the rotor to turn in the same way that a rotary lawn sprinkler turns.

PART B

MATERIALS:

piece of paper 15 x 15 cm

scissors

pin

pencil

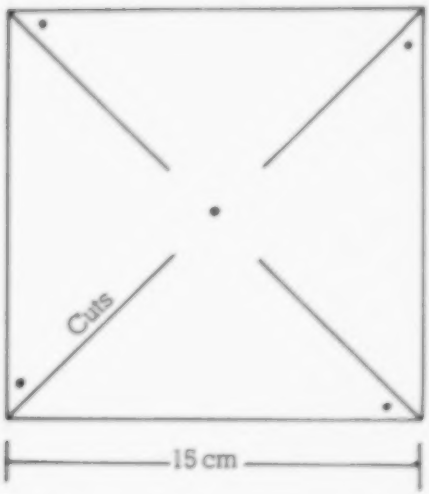
PROCEDURE:

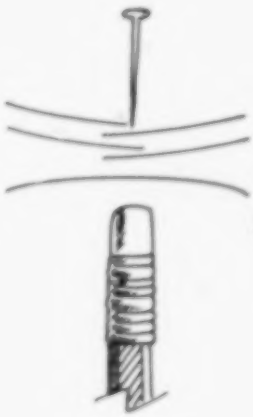
(1) Make four cuts in the paper as shown in the diagram.

(2) Bend the four corners of the paper toward its center. Place a pin through the five points indicated on the diagram.

(3) Stick the point of the pin into the end of the pencil.

(4) Drop your rotor from a window or stairwell. What happens? Explain what happens.





RESULTS:

The fall of the pinwheel is slowed by the upward thrust and the lift of the revolving pinwheel. Helicopters can land safely even when the motor stops because this thrust and lift slows their rate of fall.

F-47. HOW CAN THE FLIGHT OF A PAPER AIRPLANE BE CONTROLLED?

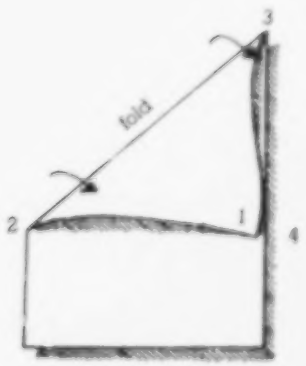
(8, 9, 10, 12, 14, 17)

MATERIALS:

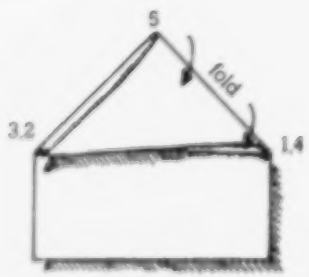
sheet of paper
ruler
scissors
tape

PROCEDURE:

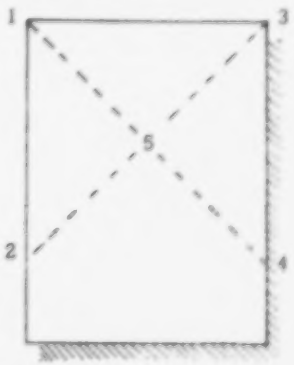
(1) Construct the paper airplane according to the diagrams.
(2) How could you cut slits in this paper airplane to better control its flight?



(1) fold point 1 down to point 4



(2) fold point 3 down to point 2



(3) open

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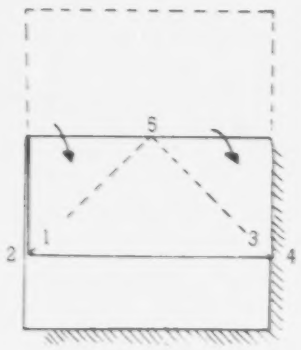
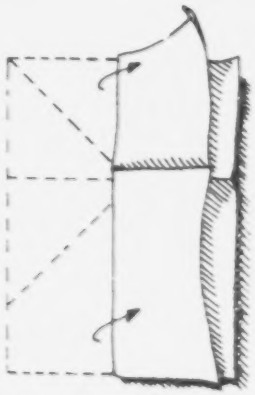
(3) Devise a plan that states your hypothesis and tells how you will test it. Check with your teacher, and then carry out your plan.

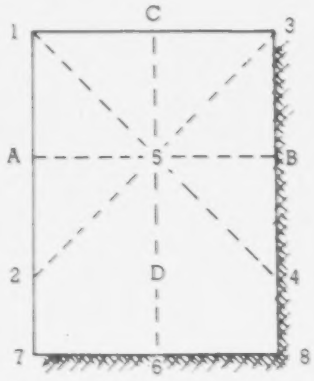
(4) Record your results and analyze them. How well was the flight of the airplane controlled? What ideas do you have for improving the flight control? Continue making and carrying out plans for your ideas until the slits you have cut control the flight of the plane. Describe how the flight of your final product is controlled.



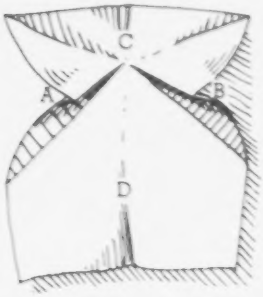
(4) fold point 1 to point 2 and point 3 to point 4

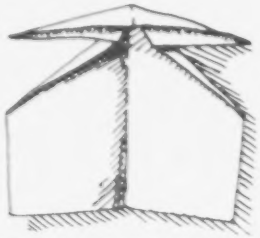


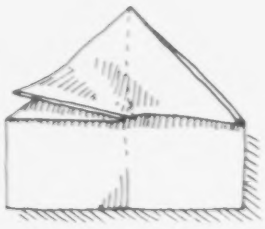
(5) open, then fold point 1 to point 3 and point 2 to point 4



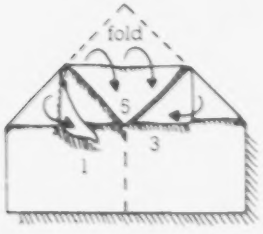
(6) open





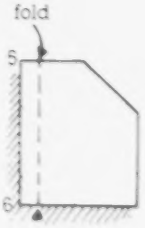


(7) bring together points A, B, C, and D

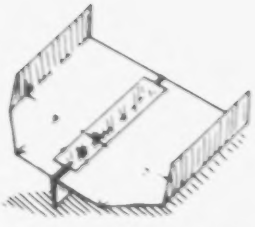


(8) fold points 1 and 3 to meet point 5

(9) fold in half along line 5-6



(10) fold down 2 cm from line 5-6



(11) tape as shown and fold up wing edges

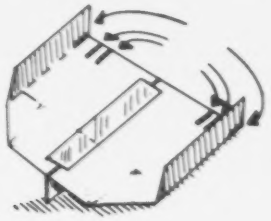
Adapted from HOLT SCIENCE, Teacher's Edition, by Abruscato, *et al.* Copyright © 1984 by Holt, Rinehart and Winston, Publishers. Adapted with the permission of the publisher.

RESULTS:

This activity is a problem-solving activity that asks students to determine how the flight of a paper airplane can be controlled. Students' results will vary. If students become frustrated, they should be encouraged or given hints or advice. For more information on problem solving, see the New York State *Elementary Science Syllabus* (1985) and Block J: *Science, Technology, and Society* (1985).

The flight of the airplane can be controlled by cutting slits in the back edge of each wing (as shown in the diagram) and bending the slits up and/or down, or left and/or right, as appropriate. The slits function as rudder, elevators, and ailerons. (A paper clip attached to the nose of the plane may help it fly better.)

(12) slits for rudder and elevators and ailerons

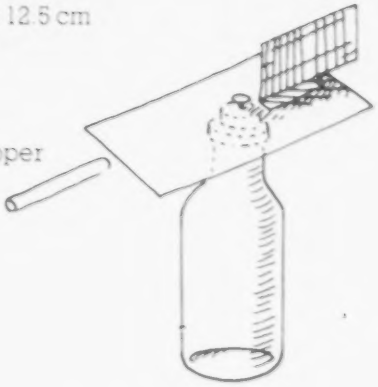


F-48. WHAT IS THE FUNCTION OF THE RUDDER AND THE ELEVATORS ON AN AIRCRAFT?

(8, 9, 14, 17)

MATERIALS:

two index cards, 7.5 x 12.5 cm
scissors
straw
thumbtack
bottle with a cork stopper
paste or glue



PROCEDURE:

(1) As shown in the diagram, cut a cardboard fin from one index card.

(2) Paste the fin to the other index card as shown.

(3) Find the point where the card balances on top of the corked bottle. Push a thumbtack through the card and cork at this point. Make sure the card can turn easily.

(4) Blow through the soda straw, directing the air across the top of the card.

(5) Turn the card slightly and again blow against the card. What happens? What is the function of this fin?

(6) How could you use the fin to make the card turn to the left or right? State your hypothesis and devise a plan to test it. Carry out your plan and report your results. Analyze your results. If your plan didn't work, try out any new ideas you have. Continue until you have a rudder that turns the card.

(7) How could you make the back of the card move up or down when you blow across the card? Make and carry out your plan as in (6) until you have elevators that raise and lower the back of the card.

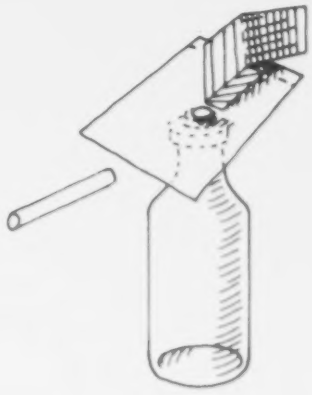
(8) Describe your rudder and elevators and how each works.

(9) How can the effects of the rudder and elevators be combined to control the movement of the card? Make and carry out your plan as in (6). Report your results.

(10) What effect do the rudder and elevators have on the direction of flight of an aircraft?

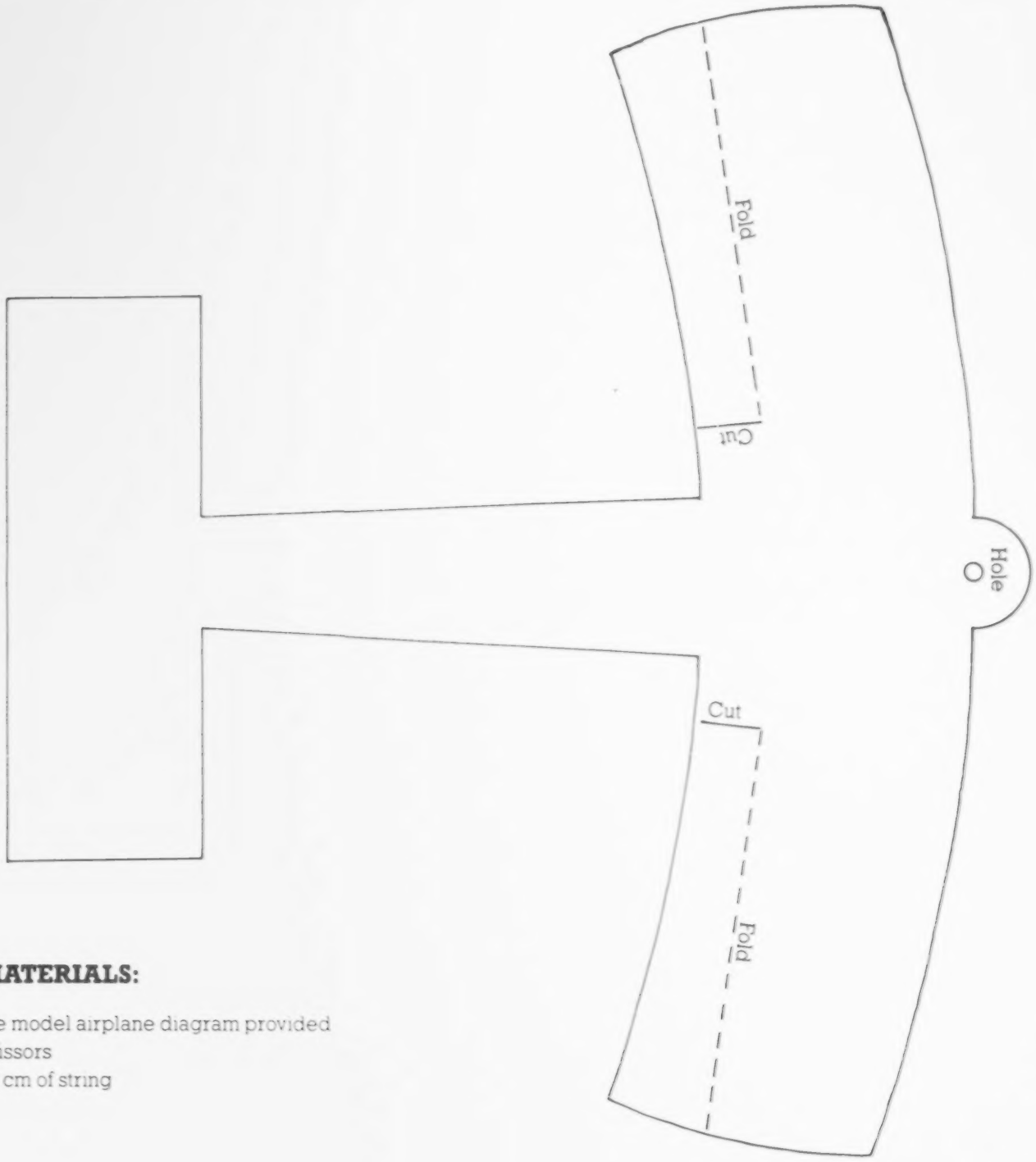
RESULTS:

The fin always causes the aircraft to face into the wind. The rudder controls the yaw, or turning motion, of the aircraft. The elevators control the pitch of the aircraft. Pushing the rudder left causes the tail to move right and the aircraft itself to turn left. Pushing the rudder right causes the reverse motion. Raising the elevators causes the tail of the aircraft to go down and the nose to go up, while lowering the elevators causes the reverse motion. A rudder and elevators function as they do because air speeds up as it moves across one of their surfaces. Faster moving air exerts less pressure. The tail of the aircraft moves in the direction of the faster moving air.



F-49. HOW DO THE AILERONS ON AN AIRCRAFT WORK?

(1, 14, 17)



MATERIALS:

the model airplane diagram provided
scissors
30 cm of string

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ADVANCE PREPARATION:

Duplicate the model airplane diagram on heavy paper.

PROCEDURE:

(1) Cut out the model airplane.
(2) Attach the string to the nose of the plane.
(3) Allow the plane to hang straight down on the end of the string.
(4) Pull the string upward slowly. What happens?
(5) Make two short cuts on the rear of the wings as shown on the model.
(6) Try folding the resulting flaps in different directions. Test each set of folds by pulling the string up slowly. What happens each time?
(7) How can you make the plane rotate clockwise? Counterclockwise?

RESULTS:

The flaps cut on the plane are its ailerons. The ailerons affect the direction in which the plane rolls or tilts.

F-50. HOW ARE LANDMARKS USED IN NAVIGATION?

(18, 19, 22)

MATERIALS:

paper

PROCEDURE:

(1) Choose a familiar local location (within 10-15 km) to take the class to on a hypothetical field trip. The class will reach this location by airplane.
(2) Devise a navigation map for the pilot to follow. Show various key landmarks to aid the pilot in locating the site.
(3) Your teacher will convert a few of the maps into overhead transparencies. After discussing these maps, answer the following questions:
   (a) Were the landmarks accurately placed on the maps? Were they clearly represented? Useful?
   (b) What other key landmarks could have been used? Why?
   (c) How difficult would it be for the pilot to locate the site? Why?
   (d) What does the pilot have to know to reach the destination safely?
   (e) How does this procedure, called pilotage, compare to dead reckoning?
   (f) What are some advantages and disadvantages of navigating by landmarks?
   (g) When is it more advantageous to use dead reckoning?
   (h) How has radio navigation improved navigation and what problems does it help solve?

RESULTS:

After discussing the maps and answering the questions, students should realize the value, difficulties, and limitations of navigating by landmarks.

F-51. HOW DOES A GYROSCOPE WORK?

(Teacher Demonstration) (1, 2, 14)

MATERIALS:

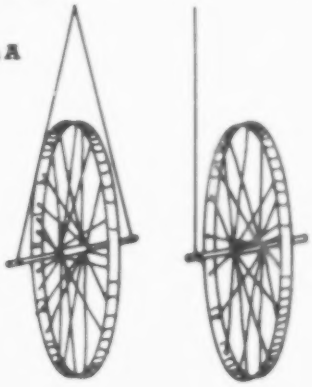
a front wheel of a bicycle
two pieces of broomstick, each 15 cm in length
two pieces of cord, each approximately 50 cm in length, depending on the size of the wheel
a toy gyroscope
45 cm of heavy string
a 50-gram mass
scissors

PROCEDURE:

PART A. Using the Bicycle Wheel as a Gyroscope

(1) Attach a piece of broomstick at each end of the axis of the bicycle wheel to provide handles (see Diagram A).
(2) Make a loop in one end of each piece of cord to fit snugly over the end of each broomstick handle.
(3) Hold the end of each cord so that the bicycle wheel is suspended from one hand.
(4) Spin the wheel. In what direction is the axis pointing?
(5) Repeat (4), but this time let go of one cord. The gyroscope is now supported by one cord. What happens? In what direction is the axis pointing? Does the direction change? If so, how?
(6) Pass the spinning gyroscope from one student to another. How difficult is it to make the gyroscope change its spin axis? What must you do to keep up with the wheel?

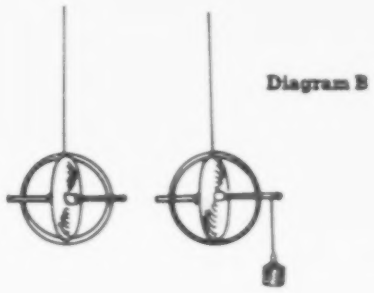
Diagram A



PART B. Using a Toy Gyroscope

(1) Suspend a toy gyroscope from its center of gravity (see Diagram B). Start the gyroscope spinning. What happens?
(2) Slowly move the gyroscope. Make sure the motion is not sudden. What happens?
(3) Suspend the 50-gram mass from one end of the gyroscope's frame (see Diagram B). What happens?
(4) Is a spinning top a gyroscope? Why or why not?

Diagram B



RESULTS:

A spinning gyroscope is stable and it is difficult to change the position of its axis of spin. A spinning gyroscope exhibits inertia and tends to stay in motion. As the speed of the spinning gyroscope increases, its inertia increases, and more force is needed to change its axis of spin.

As the bicycle wheel gyroscope spins, the outside end of its axis describes a circle (precesses). The bicycle wheel will actually turn around in a circle.

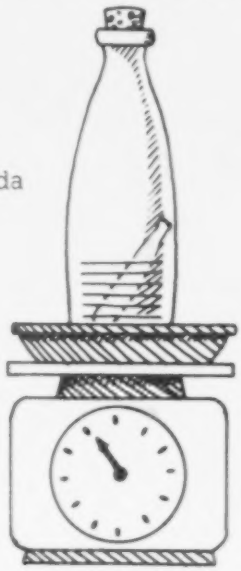
As the toy gyroscope is tilted from its vertical plane of spin, its axis will also describe a circle. When a mass is hung on one end of the gyroscope's axis, the other end will circle around the mass.

F-52. WHAT IS THRUST AND HOW CAN IT BE MEASURED?

(1, 14, 17)

MATERIALS:

a refillable soft-drink bottle with a cork to fit the top
household scale
small pan
one tablespoon of vinegar
one cup of water
facial tissue
one tablespoon of baking soda
small towel
safety glasses



PROCEDURE:

Caution: Use a heavy glass bottle. A non-refillable bottle may shatter. Wear safety glasses.

(1) Add one tablespoon of vinegar to a cup of water.
(2) Pour this solution into the soda bottle.
(3) Wrap a tablespoon of baking soda in a small square of facial tissue.
(4) Arrange the bottle, pan, and scale as shown in the diagram. Wrap a small towel around the bottle.
(5) Drop the tissue paper containing the baking soda into the bottle and immediately cork it lightly.
(6) Watch the scale carefully. What happens to the bottle? Why? What happens to the scale? Why?
(7) Would the thrust register on the scale if the bottle were placed on its side? How would you solve this problem? After checking with your teacher, carry out your plan. (A little ingenuity and less vinegar mixture are required to prevent a mess on the floor.)
(8) How does what happened in this activity compare to how a rocket works?

RESULTS:

Thrust (the reaction force) occurs within the bottle in response to the action force, which is the exhausting of the built-up gases from the opening in the bottle. This thrust can be measured with a scale.

F-53. HOW DOES INERTIA AFFECT THRUST?

(1, 14, 17)

MATERIALS:

a small mass such as a fishing sinker or metal sphere
rubber band
a wide-mouth plastic bottle such as a food jar
piece of dowel

PROCEDURE:

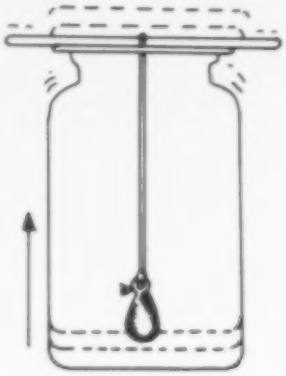
(1) Attach the mass to one end of the rubber band.
(2) Slip the dowel through the other end of the rubber band and place in the jar as shown in the diagram.

(3) When is the system in equilibrium?
(4) Thrust the bottle upward. What happens to the length of the rubber band? Explain why you think this happened.
(5) Thrust the bottle downward. What happens to the length of the rubber band? Explain why you think this happened.

RESULTS:

When the apparatus is initially assembled, the rubber band stretches until the tension on it equals the weight of the suspended mass. The system is then said to be in equilibrium.

When the bottle is thrust upward, the rubber band lengthens as a result of the inertia of the suspended mass. The mass appears to be heavier because the rubber band is longer than before. (An astronaut also exhibits an apparent increase in weight upon space launch.) It is this apparent increase in weight (or inertia) that thrust must act on for a space vehicle to achieve space flight.



Thrusting upward

F-54. HOW CAN WE DEMONSTRATE A CLOSED ORBIT?

(18, 20, 22)

MATERIALS:

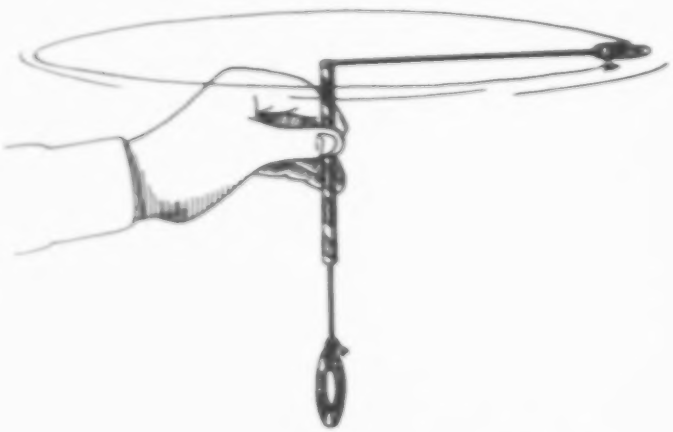
plastic straw
30 cm of heavy thread
small paper clip
a large washer or other mass
safety glasses

PROCEDURE:

(1) Cut the straw in half. String the thread through the straw. Tie the paper clip to one end and the mass to the other end of the thread.
(2) Hold the straw upright in one hand and the mass in the other. Start swinging the paper clip horizontally around the top end of the straw, as shown in the diagram.

Caution: Wear safety glasses while swinging the paper clip.

(3) Keep swinging the paper clip in a smooth motion. Do not swing it too hard. Let go of the mass. Slow the swing of the paper clip. What happens to the mass? Swing the paper clip faster. What happens to the mass?
(4) Create a stable orbit, where the mass does not move up or down, but is also not held against the bottom of the straw. Is the force exerted by the paper clip's orbit equal to the weight of the mass? Why or why not?
(5) How is this system like a space vehicle orbiting Earth? Compare the forces in each system.
(6) Swing the paper clip faster. What happens to the radius of the orbit? Swing the paper clip slower. What happens to the radius of the orbit now?



(7) How is the speed of orbit of a space vehicle related to its altitude of orbit? As the altitude of the orbit increases, what happens to the force of gravity acting on the space vehicle?

(8) Pull down on the mass to simulate increased gravity acting between the paper clip and the mass. What happens to the radius of the orbit? What happens to the speed of orbit? Let go of the mass. What happens to the radius and speed now?

(9) As the altitude of a space vehicle decreases and the force of gravity increases, what has to happen for the vehicle to stay in orbit? Why?

RESULTS:

For a space vehicle to achieve orbit, gravity and orbital speed must be balanced. This is shown in (4) and (5), where the forces are balanced. The mass' weight represents the force of gravity between the mass and paper clip. The person swinging the clip provides the energy to maintain the orbital speed. Steps (6)-(9) illustrate the relationship between orbital altitude, orbital speed, and gravity. Speed of orbit is inversely proportional to orbital altitude. To remain in orbit, a space vehicle in a lower orbit must maintain a higher speed than one in a higher orbit.

F-55. HOW CAN WE DEMONSTRATE WEIGHTLESSNESS?

(1, 18, 14, 17)

MATERIALS:

a wide-mouth plastic bottle such as a food jar
a fishing sinker or similar mass
a long rubber band
dowel
pillow

or

two paper clips
one rubber band

Diagram A

PROCEDURE:

(1) Assemble either set of materials as shown in the appropriate diagram.

(2) Hold either setup as high in the air as possible.

Caution: Drop the plastic bottle only onto a pillow.

(3) Drop the setup you are holding and observe it carefully as it falls.

(4) What happens? Try to explain why it happens.

(5) At what moment did the bottom paper clip or the mass appear to be weightless? How do you know?

(6) Discuss the results of this activity with your teacher. What experiences have you had that are similar to what happened here? Did they give you a feeling of weightlessness?

Diagram B

RESULTS:

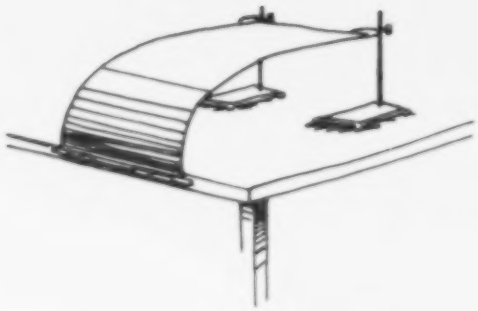
Since mass appears to be weightless during free fall, the rubber band in either setup will contract, pulling the lower paper clip upward in the second setup, and even causing the sinker to come out of the bottle in the first setup. People experience a feeling of weightlessness when moving down a fast elevator or when an airplane takes a sudden drop in altitude. Astronauts practice manuveuring under weightless conditions in aircraft flying in an arc. When the aircraft goes "over the hump," the astronauts experience 30-45 seconds of free fall or weightlessness.

F-56. HOW CAN WE DEMONSTRATE ESCAPE VELOCITY AND RETURN TO EARTH?

(18, 20, 22)

MATERIALS:

a large sheet of poster board
tape
two ring stands, each with a burette clamp
a marble



PROCEDURE:

(1) As shown in the diagram, fasten one end of the piece of poster board to the edge of a table and bend it back in a smooth curve.

(2) Secure the other end of the poster board to the burette clamps on the ring stands. The surface of the higher end of the poster board should be almost horizontal.

(3) Place the marble at various heights along the slope and let it roll down the slope. How does the height of the marble on the slope affect the marble's rate of motion?

(4) To see how a space vehicle moves as it is launched from Earth's surface, roll the marble up the slope from the lowest edge.

(5) If you roll the marble harder, what happens to its speed up the slope? What is the effect of increasing the speed (velocity) of the marble up the slope?

(6) To simulate a launch from a space station, rather than from Earth, repeat (4) and (5), but this time start from a point well up the incline instead of from the lowest edge.

(7) In which situation, (4) or (6), did the marble require less speed to reach the end of the poster board? Of what importance is this finding?

(8) What effect does mass have on the escape velocity of an object? State your hypothesis, plan how you would test it, and carry out your plan. Report your results and conclusion.

RESULTS:

Step (3) illustrates how gravity affects an object at varying distances from Earth. The curved cardboard represents the decreasing force of gravity with increased distance from Earth. Since the lowest part of the poster board is vertical, when the marble is released there it will fall with the uniform acceleration of gravity. This represents the force of gravity near Earth. When the marble is placed near the highest edge of the slope, it will pick up speed very gradually. This represents the force of gravity so distant from Earth that an object's weight is only a fraction of its Earth weight. Step (3) also shows how gravity affects the return of a space vehicle to Earth.

Steps (4) and (5) show the effect of increased speed on escape from Earth orbit. At low velocities, the marble slows and returns to the bottom. A critical velocity is reached where the marble continues up the slope and leaves the cardboard. This velocity can be likened to the escape velocity needed for a space vehicle to leave Earth orbit.

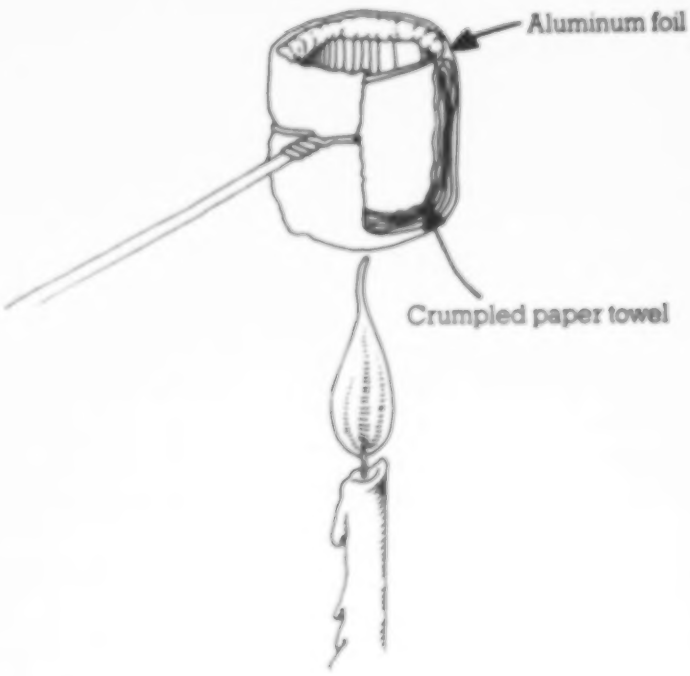
When the marble is launched from a point well up the incline, a lower velocity is needed to escape from the cardboard (gravity). This represents launching a space vehicle from a space station.

F-57. HOW DOES A HEAT SHIELD WORK?

(1, 14, 17)

MATERIALS:

paper towels
aluminum foil
paper cup (175-250 ml)
coat hanger or wire
candle
thermometer
water
tape
matches
safety glasses



PROCEDURE:

(1) Crumple a paper towel around the outside of a paper cup, as shown in the diagram.
(2) Cover the paper towel layer with two layers of aluminum foil.
(3) Apply another layer of loosely-crumpled paper towel.
(4) Add a final covering of aluminum foil and tape it securely to the top edge of the cup.
(5) Make a holder for the "insulated" cup with the coat hanger or wire.
(6) Place 60 ml of water in the cup. Record the temperature of the water in the cup.

Caution: Wear safety glasses.

(7) Place the cup in the flame of the candle for one minute. Record the temperature of the water again.
(8) What was the difference in the temperature of the water before and after it was heated?
(9) How did the coverings affect the change in temperature of the water? What do you think would have happened to the temperature of the water if the cup was not covered as it was?
(10) How would reducing the amount of insulation affect the change in temperature of the water? State your hypothesis, plan your investigation, and carry it out only after you receive your teacher's approval. Record your results and state your conclusion.

Caution: Always leave at least one layer of aluminum foil around the cup to keep it from catching fire.

RESULTS:

If the cup was properly insulated, the temperature of the water should not rise more than 1°C. The space shuttle uses silica tiles and fiberglass-covered silica blankets which insulate in the manner demonstrated in this activity. Other space programs employed ablative materials that were used up as they absorbed heat. You can illustrate this by freezing a thermometer in an ice cube, then placing the ice cube in the candle flame and observing the temperature of the thermometer.

Proper insulation on a space vehicle protects the vehicle and astronauts from dangerously high temperatures.

SOURCE: NASA

F-58. WHAT KINDS OF EXERCISES COULD SPACE TRAVELERS DO UNDER WEIGHTLESS CONDITIONS?

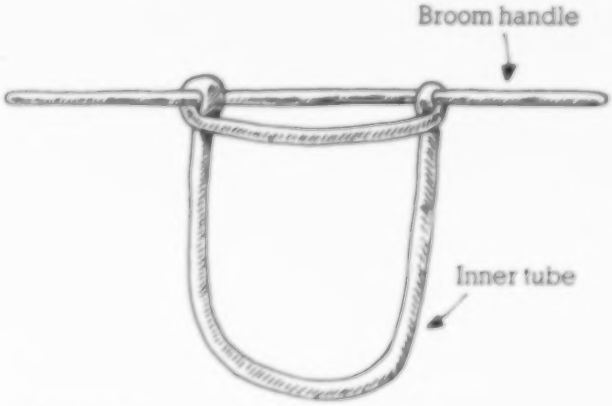
(1, 14, 17)

MATERIALS:

bicycle inner tube
broom handle
watch or clock that measures seconds

PROCEDURE:

(1) Assemble the "bungee cord" by loop hitching the bicycle inner tube around the middle of the section of broom handle and tightening securely, as shown in the diagram.
(2) Count your pulse beats for 10 seconds and record the number.
(3) Hold the bungee handle with both hands and place one foot in the open end of the loop ("foot strap").
(4) Pull the bungee against the foot and release.
(5) Repeat (4) at the rate of one pull per second for 30 seconds. Ask a fellow student to time you.
(6) Change to the other foot and repeat (5).
(7) Immediately count your pulse beats for 10 seconds and record the number. What happened to your pulse rate? Why? How did your muscle sensations change? Why?
(8) Grasp your right hand with your left hand, palms facing each other, and pull your hands in opposite directions for 5, 10, and then 20 seconds. How do your muscle sensations change?
(9) Clasp your hands around one knee. Pull your knee toward your chest 12 times. Repeat with the other knee. How do your muscle sensations change?
(10) Could astronauts do the exercises you have just performed in the weightless conditions of space? Why or why not?



RESULTS:

Pulse rate will increase with the first exercise and muscles will begin to feel tired with all exercises. These are the kinds of exercises that astronauts perform in space to avoid losing muscle tone and strength.

SOURCE: NASA

F-59. WHAT HAVE THE ASTRONAUTS ACCOMPLISHED?

(14, 17)

MATERIALS:

various references from NASA
library references

ADVANCE PREPARATION:

You may wish to more carefully delimit this activity by allowing students to select only space shuttle astronauts or by allowing students to select only from a small list of astronauts, each of which is drawn from one of the space programs. This second alternative allows students to compare the programs and see how they progressed.

PROCEDURE:

(1) Select an astronaut and research the person's part in, and contribution to, the space programs.
(2) Plan an "astronaut reunion" to be held during class.
(3) Come prepared in the following ways:
   (a) Be able to discuss your astronaut's mission and flight (purpose, significant findings, etc.).
   (b) Be able to discuss any problems the mission encountered (safety, weather, postponements, changes, etc.).
   (c) Bring to the reunion a sample of the astronaut's favorite space food.
   (d) (OPTIONAL) Dress in a copy of the astronaut's space suit or work uniform and be able to discuss it.

F-60. WHAT IS IT LIKE TO WALK AND WORK ON THE MOON?

(14, 17)

PROCEDURE:

(1) Read and analyze the story provided. List the obvious errors in the story.
(2) Write a new version of the story to produce a more accurate description of the Moon's environment. Make a special effort to include safety precautions the astronauts must take while on the Moon. How does the lack of an atmosphere affect them? The Moon's gravity? How are eating, talking, smelling, seeing, hearing, touching, drinking, walking, and body temperature affected?

As the two American astronauts walked slowly over the Moon's rugged surface, they saw thousands of stars twinkling brightly in the black lunar sky. A light breeze blew some Moon dust up against the clear glass of their helmets. The astronauts watched the Sun rising slowly in the east as the beautiful crescent Earth set in the west. Between the horns of the crescent, the planet Venus shone like a jewel.

Hearing a loud crash, the astronauts turned to see a meteor streak across the sky and impact the lunar surface about 15 kilometers away. Through the haze, they saw the command module moving swiftly overhead. They quickly ignited a flare and sent it up on a helium balloon to signal their position to the third astronaut in lunar orbit. As the astronauts relaxed, enjoying the brilliant colors of the lunar sunset, one of them remarked, "What a great place to spend a vacation...."

SOURCE: Roberson-Kopernik Observatory, Binghamton, N.Y.

RESULTS:

This creative writing activity allows students to extend their understanding of the unique environment that is the Moon.

A film loop, "The Ups and Downs of Being an Astronaut," is available from the American Association of Physics Teachers, Publications Department, 5110 Roanoke Place, Suite 101, College Park, MD. The film is of an actual Moon walk.

F-61. HOW IS THE TEMPERATURE INSIDE A SPACE SUIT CONTROLLED?

(1, 14, 17)

MATERIALS:

thermometer
string

a heavy, button-up raincoat
high boots
watch or clock
chair
15 meters of small-diameter hose or rubber tubing

PROCEDURE:

(1) Attach the thermometer to the string. Tie the string around a student volunteer's neck so that the thermometer is suspended at mid-chest level. Record the temperature.
(2) Wrap the hose around the volunteer's midriff at least 20-30 times. Attach one end of the hose to a source of cool water and place the other end in a drain. *Do not turn on the water yet.*
(3) Ask the volunteer to put on the boots and the raincoat, and to button up the raincoat completely. Have the volunteer sit quietly on a chair for five minutes.
(4) After the five-minute period, read and record the temperature again. What caused the change? How would an astronaut in a space suit be affected?
(5) Turn on the water and let it flow for five minutes. Read and record the temperature.
(6) Ask the volunteer to explain whether the flow of cool water makes any difference in comfort.
(7) If other students wish to, and time permits, allow them to try the demonstration.

RESULTS:

Heat from the student's body will build up under the raincoat, much as it would build up in an insulated space suit. In a space suit called the Liquid Cooling Garment (LCG), circulation of cool water through thin plastic tubing held close to the skin of primarily the torso and thighs causes a cooling effect.

SOURCE: NASA

F-62. WHAT IS OUR FUTURE IN SPACE?

(14, 17)

MATERIALS:

reference sources

PROCEDURE:

(1) Ask students to choose and research one of the following topics, or another topic of their choice approved by you.
Our future is in our space program.
Should we use our space technology for military endeavors?
Will (or should) citizens travel in space?
Space colonies: A reality or fantasy?
(2) Following the students' research, ask each student to take a pro or con position on the topic. Positions can be supported during a class debate of the topic.

F-63. WHAT WOULD YOU NEED TO TRAVEL TO MARS?

(14, 17)

MATERIALS:

reference sources

PROCEDURE:

(1) As a class, plan a space trip to Mars. What would you need to get there? To survive there? Each class member can research and report on one of the following problems. Or you can research your own problem concerning space travel.

What kind of space vehicle would you use? What would be its approximate mass?
What would you have to carry with you during your trip?

What fuel would you use and how much of it would you need?

How would you get off the ground? How much thrust would it take?

How much thrust would it take to escape Earth orbit? To move toward Mars?

How would you navigate?

How would you land on Mars?

How long would the trip take?

How long would you spend on Mars?

How long would it take to return to Earth?

How would you keep time?

What support devices would you need to leave the space vehicle and explore Mars?

What would you need to set up a space colony on Mars?

(2) After each student has reported on one aspect of the problem of getting to Mars, put together an overall plan that considers all of the aspects.